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IMPACT OF LANDFILL LEACHATE ON THE QUALITY OF GROUNDWATER AT AGBANI METROPOLIS, ENUGU STATE

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ABSTRACT: This study assessed the impact of landfill leachate on the quality of groundwater obtained at Agbani metropolis in Enugu state, Nigeria. Specifically, the study focused on analyzing the physiochemical and bacteriological contents of the groundwater obtained from the wells close to the dumpsites, with a view to recommending whether the water is good for human consumption. The study used a total sample of six (6) wells with borehole water as control. Thirty-one (31) parameters comprising nine (9) physical parameters, eleven (11) chemical parameters, eight (8) heavy metals, and three (3) bacteriological parameters. These parameters are; Temperature (^0C), turbidity, taste, odour, colour, Electrical conductivity (EC), total solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), pH, total acidity, total alkalinity, Chloride (Cl^-), total hardness, phosphate, sulphate (SO_4^{2-}), Dissolved Oxygen (DO), Nitrate ($N0_3^-$), Magnesium Hardness, Calcium Hardness, Zinc (Zn), Lead (Pb), Copper (Cu), Arsenic (As), Manganese (Mn), Chromium (Cr^{3+}), Iron (Fe), and Magnesium (Mg). The criteria behind selection of these parameters were based on the parameters being the common pollutant elements in groundwater around the dumpsites. All tests were performed as per standard methods while the water quality was compared with both Nigerian and WHO recommended standards for drinking water. Analytical techniques employed in the quantitative data analysis were descriptive statistics such as mean, standard deviation and graphical representation, as well as inferential statistics like student's t-test with the aid of IBM-SPSS 25.0. Results uncovered that Most of these parameters indicated traceable pollution but were below the World Health Organization (WHO) and Nigerian Standard for Drinking water quality (NSDWQ) limits for consumption. Specifically, it was ascertained that most of the chemical parameters (Total Hardness, Chlorides, Phosphates, Sulphates, Magnesium, Zinc, Manganese and Chromium) showed a 100% compliance with WHO standards. However, some other constituents in the water exceeded the recommended WHO standard for drinking water; hence, the groundwater of the area is termed polluted and not fit for human consumption. Also, the study revealed that water quality in terms of bacterial account did not conform to the WHO water quality standard and Nigerian Standard for Drinking Water Quality. However, it was suggested that there is need for proper treatment of groundwater in this area before domestic use.

KEYWORD: Effluents, Industrialization, Quality, Groundwater, Landfills.

I. INTRODUCTION

Water is an essential thing in our day-to-day life (Jamuna, 2018). Ground water occurs almost everywhere below the land surface. Ground water exists in the world about 0.6%; even though its contribution is less, it is fresh source of water supply. Ground water is the one which is subjected to less pollution compared to surface water sources. Unfortunately, nowadays, the ground water is getting polluted due to increase in population, urbanization and industrialization. Also, the unsafe disposal of industrial effluents and hazardous waste into natural water bodies may lead to minor to severe ill effects on human bodies those who largely depends on ground water. The impact of human activities towards ground water may also alter the quality of ground water. Therefore, it becomes essential to access the quality of ground water and to monitor them periodically. Leachate is one of the main sources of groundwater and surface water pollution(Lahiru-Lindamulla et al.,2022). If it is not properly collected and treated and safely disposed, it may percolate through soil reaching water aquifers (Tursunov & Abduganiev, 2020). Therefore, the current study focuses on the impact of landfills leachate on the groundwater generated in Agbani, Enugu state.

Landfills have been identified as one of the major threats to groundwater resources (Fatta et al., 1999) not only in India but throughout the world (United States Environmental Protection Agency US EPA 2004). More than 90% of the Municipal Solid Waste (MSW) generated in India is directly dumped on land in an unsatisfactory manner (Chatterjee, 2010). The solid waste placed in landfills or open dumps are subjected to either groundwater underflow or infiltration from precipitation or any other possibility of infiltration of water. During rainfall, the dumped solid wastes receive water and the by-products of its decomposition move into the water through the waste deposition. The liquid containing innumerable organic and inorganic compounds is called 'leachate'. This leachate accumulates at the bottom of the landfill and percolates through the soil and reaches the groundwater (Mor et al., 2006).

Areas near landfills have a greater possibility of groundwater contamination because of the potential pollution source of leachate originating from the nearby dumping site. Such contamination of groundwater results in a substantial risk to local groundwater resource user and to the natural environment. The impact of landfill leachate on the surface and groundwater has given rise to a number of studies in recent years and gained major importance due to drastic increase in population (Saarela, 2003). There are many approaches that can be used to assess the groundwater and surface water contamination. It can be assessed either by the experimental determination of the impurities or their estimation through mathematical modeling (Moo-Young et al., 2004).

In the present study, the impact of leachate percolation on groundwater quality was estimated from an unlined landfill site at Vendipalayam, Semur and Vairapalayam of Erode District, Tamil Nadu, India(Subramani et al., 2012). Various physicochemical parameters including heavy metals were analyzed in the leachate and in groundwater samples to understand the possible link of groundwater contamination. The effect of depth and distance of landfill from groundwater sources were also studied and some remedial measures were discussed to reduce further contamination of groundwater.

Contamination of drinking water sources by sewage can occur from raw sewage overflow, septic tanks, leaking sewer lines, land application of sludge and partially treated waste water. Sewage itself is a multifaceted mixture and can contain many types of contaminants (Pedersen, 1997). The greatest threats posed to water resources arise from contamination by bacteria, nitrates, metals, trace quantities of toxic materials, and salts. Seepage overflow into drinking water sources can cause disease from the ingestion of microorganisms such as E. coli, Giardia, Cryptosporidium, Hepatitis A, and helminths.

The problems associated with sewage disposal have become a major problem of the urban world due to increase in human population and urbanization. The commonality of sewage related problems throughout the world is important since these areas. Consequently, domestic wastewater discharges are considered one of the most significant threats to human environments worldwide. Environmental effects associated with domestic waste-water discharges are generally local with trans-boundary implications in some areas.

Groundwater is the water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. But unfortunately, groundwater in both urban and rural areas can be polluted as a result of human activities (Naomi et al., 2019).

According to Owa(2013),the concept 'water pollution' simply means contamination of water due to any external material, in other words, water pollution is the introduction of something to natural water which makes unsuitable for human consumption. There is no doubt that water pollution is the result of the human activity. Water quality refers to the chemical, physical and biological characteristics of water, water quality measure of the condition of water relative to the requirements of one or more biotic species and/or to any human need or purpose. It is frequently referred to as a set of standards against which compliance can be assessed. The most common standards used to assess water quality relate to health of ecosystem, safety of human contact and safety of drinking water (Arjun-Ram et al.,2021). Today, 1.1 billion people live without access to qualitative sources of water and 2.4 billion people without access to sanitation (Jidauna etal.,2013). Even though the percentage of the global population represented by these figures decreased significantly between 1990 and 2006 (United Nations Development Programme, 2006), the number of people lacking safe water decreased very little during the abovementioned period and the number of people without sanitation even increased due to population growth(Guerquin, 2003).

Similarly, this situation is not different from what is currently obtainable in Nigeria and Africa. United Nation Children Education Fund (UNICEF) Joint Monitoring Programme for Water Supply and Sanitation reported that only 58 percent of Nigerian population has access to improved drinking water supply and sanitation coverage stands at only about 32 per cent (World Health Organisation (WHO) and UNICEF Report, 2005). Nigeria with an estimated population of about 160 million, about 64 million people are without access to improved drinking water and over 100 million people do not have access to improved sanitation this situation forced many people to drink polluted water obtained from other unsafe available sources thereby exposing them to hazardous chemicals and infectious agents.For that reason, the need to access a reliable, secure, safe, and sufficient source of fresh water is a fundamental requirement for the survival, well-being, and socio-economic development of all humanity.

Access to safe drinking water is essential to health. It is a basic human right (WHO)Therefore, an adequate and safe supply of water is essential for development. The World Health Organization's 2002 estimates showed that more people die each year from the consequences of unsafe or inadequate water supplies than from all forms of violence (WHO). Groundwater has become an indispensable source of drinking water worldwide and especially in developing countries. The 2006 Nigerian household population census revealed that 49.4% of sampled households depend on groundwater as the main source of water for domestic use. This high dependence stems from the fact that groundwater is thought to be free of the pathogens widely found in surface waters (EawagNews, 2011), However, groundwater may contain a wide variety of dissolved inorganic chemical constituents resulting from interactions between water and geologic materials. These geogenic contaminants can have a negative effect on human health.

Geogenic contaminants affect the health of hundreds of millions of people worldwide, it is estimated that around 200 million people worldwide are affected by arsenic and fluoride contamination alone, roughly 5 per cent of all those who use groundwater for drinking (Amini et al., 2021). The health implications of the ingestion of arsenic contaminated drinking water include dermal lesions such as hyperpigmentation and hypopigmentation, peripheral neuropathy, skin cancer, bladder, lung and kidney cancers and peripheral vascular diseases (IPCS; Amini et al., 2021, WHO, 2011). The ingestion of elevated concentrations of fluoride leads to dental and skeletal fluorosis (Edmunds & Smedley,2013; WHO, 2011).

In spite of the health risks associated with the ingestion of groundwater with elevated concentration of As. and F., few studies have been conducted to determine the scale of As and F contamination of groundwater in Nigeria and even fewer studies on user's awareness of geogenic contamination. The knowledge of areas with elevated geogenic contaminants in Nigeria is of critical importance in safeguarding the health of the citizens, since the majority of people (especially the urban and rural poor) depend on untreated groundwater for domestic purposes. This study therefore aims at analysing the concentration of arsenic and fluoride in groundwater from hand-dug wells in the Ibadan region so as to reveal areas (if any) with elevated concentration of arsenic or fluoride. In addition, the study will determine the level of awareness of geogenic contamination among well owners and users within the study area.

II. LITERATURE REVIEW

This chapter is the review of the related studies to this work. Specifically, this chapter will review the concept of sewage, water quality and groundwater pollution as well as the physical, chemical and biological characteristic of drinking water, as well as their health implications.

The influence of leachate on groundwater sources near the landfill sites of Erode city. The metals Pb, Cd, Cr and Ni are characterized as toxic one for drinking water. The migration of metals is likely a product of some parameters including soil sorption capacity, reaction rate of these elements with solid phase, water movement rate in the soil and their primary concentration (Behbahaninia et al., 2003). The concentration of these metals, however, was found to be below detection limits in groundwater samples of the Erode city. Even though there may be migration of contaminants into groundwater, the level was below detectable range. This likely indicates that these metals may be adsorbed by the soil strata or by the organic matter in soil. The leachate is generally a strong reducing liquid formed under methanogenic conditions and on coming into contact with aquifer materials has the ability to reduce sorbed heavy metals in the aquifer matrix. The most important reactions are the reduction of Fe and Mn to more soluble species. Hence, the concentration of these components increases under favorable conditions close to a landfill and may lead to a serious toxic risk.

In developing countries, landfills have been largely unsuccessful because the landfill sites have a very limited time frame of usage (Meegoda et al., 2006). It is also receiving Municipal Solid Waste (MSW), commercial and industrial wastes which may contain hazardous substances and can increase the health risks emanating from the leachate and gases (Tursunov et al., 2020).

In 1999, 23% of the collected solid waste from Alexandria, Egypt, was recovered for compost production. The remaining 77% was open dumped in an uncontrolled manner on both the banks of Maryout Lake and three open dump sites, causing (Tursunov et al., 2017). Nowadays, sanitary landfilling became the main disposal method where 78% of the generated solid waste is transferred to sanitary landfill and the remaining 22% is recovered for compost production (Tursunov et al., 2019).

Over 20–30 years MSW in closed landfill cells is converting into solids. Amin et al.(2021), leachate is one of the main sources of groundwater and surface water pollution if it is not properly collected and treated and safely disposed as it may percolate through soil reaching water aquifers (Vaverková, 2019). Therefore, the current study focuses on the characteristics of leachate generated from landfill sites in Alexandria, Egypt and its impacts on the groundwater quality.

Lahiru et al.(2022) evaluated landfill leachate characteristics and found the mean values of41,637 µS/cm and 30,083 mg/l, respectively. This finding confirmed the results of the present study where the range of conductivity extended from 35,260 to 42,857 µS/cm with a mean value of 40,921 µS/cm and the mean value of dissolved inorganic solids was 27,452 mg/l. Lower results were obtained by Bahaa-eldin et al.(2010), found that the conductivity of the leachate from the landfill in Malaysia was 31.68 µS/cm. Although, (Olivero-Verbel et al., 2005; Magda & Gaber, 2014)showed that leachates collected from landfill in Egypt had high conductivity, these values were lower than those found in the present study.

In the present study, chlorides widely ranged from 9500 to 16,250 mg/l with a mean value of 11,387 mg/l. Lower chloride values (2050; 5680 and 7000 mg/l) than those of the present study were observed by (Bahaa-eldin et al., 2008; Magda & Gaber, 2014;), respectively.

In the current study, BOD ranged between 9620 and 11,700 mg/l with a mean value of 10,824 mg/l and COD values ranged between 12,850 and 16,350 mg/l with an average of 15,629 mg/l. Ratio of BOD_5/COD (0.69) indicated that the leachate had high through anaerobic phase.Magda and Gaber (2014) studied the leachate originating from the El-Jahad municipal landfill in Egypt found that the leachate had the mean values of COD and BOD_5 of 1000 mg/l and 60 mg/l, respectively. The ratio BOD_5 to COD was 0.06. This indicates that the leachate was stabilized and the landfill was in the methanic phase of anaerobic degradation. The results of the current study were in contradiction with Monje-Ramirez and Orta de Velásquez who found that leachates obtained from the Bordo Poniente, Mexico sanitary landfill were well-stabilized (BOD_5/COD < 0.01); on the average, they had a COD of 5000 mg/l, and a BOD_5 of 20 mg/l. Although, higher mean values of BOD and COD (28,833 and 45,240 mg/l; respectively) than those of the present study were reported by Hassan and Ramadan (2016) thatthe ratio BOD_5 to COD of their study was 0.63 which is similar to the current study results. Chen (2006) studied the effects of landfill age and rainfall on landfill leachate in Taiwan, the results showed that BOD and COD concentrations (296 and 3340 mg/l, respectively) were below the values of the present study and indicated that the leachate had reached the mature stage.

Young leachates are more polluted than the mature ones where BOD_5 may reach up to 81,000 mg/l for young and 4200 mg/l for mature samples. BOD_5/COD ratio in young landfill, where biological activity corresponds to the acid phase of anaerobic degradation, reaches values of 0.85 (Vaverková, 2017). Old landfills produce stabilized leachate with relatively low COD and low biodegradability (BOD_5:COD ratio < 0.1) (Tursunov & Abduganiev, 2020).

In the present study, the variation in different parameters values may be attributed to the fluctuations in waste type and characteristics, the absence of waste shredding before disposal, compaction of the waste which retards degradation, and landfilling. Observed ammonia concentrations ranged from 190 to 410 mg/l with a mean value of 321 mg/l. At this concentration the methanogenic is only slightly inhibited by ammonia, but at higher values of pH and temperature, such that the equilibrium shift NH_4 to NH_3, the latter that is more toxic can cause inhibition of the methanogenic archaea. Higher mean values of ammonia concentrations (600 mg/l) than those reported in the present study were obtained by Hassan and Ramadan (2005).

In the present study, it is expected that the mean values of total Kjeldahl nitrogen (583 mg/l) and phosphates (0.37 mg/l) decrease during the stabilization process as found by Hassan and Ramadan (2017) (mean values of 973 mg/l for total nitrogen and 0.33 mg/l for total phosphate). This may be attributed to the compaction of the wastes in the landfill. In mature leachate ammonia-NH_3/total Kjeldahl is usually greater than 70%. In the leachate under study, ammonia-NH_3 represents 55% of total nitrogen and was not yet complete then nitrates or nitrites have not been produced.

In Morocco, Chofqi et al. (2002) collected leachate samples from El-Jadida landfill and the mean results showed that the leachate had high concentrations of nitrates and sulfates (290 mg/l and 1150 mg/l, respectively). High nitrate values indicate that the environment was oxidized, thus the sulfate reduction not occurred, so sulfate concentrations were higher than those of the present study where sulfates and nitrates had mean concentrations of 596 mg/l and 1.4 mg/l, respectively. In our study, sulfate may be resulted from the decomposition of proteins. In addition, the leachate organic matter has not been fully biodegraded yet and sulfur has not been released; therefore, the sulfate concentrations were lower than those found by Chofqi et al. (2000). On the other hand, the results of the current study agreed with Hassan and Ramadan (2004) who found that nitrates and sulfates values of landfill leachate had low mean concentrations with a mean value of 1.0 mg/l and 535 mg/l, respectively. Hassan and Ramadan (2004) revealed that although landfills are considered anaerobic environments, oxygen input can occur from heterogeneous mixture of wastes and Oxidizing conditions in the landfill may cause volatilization and nitrification reactions. Volatilization leaves enriched free ammonia-NH_3 while nitrification converts ammonia to nitrate, consequently lead to increase in nitrate concentrations. However, the more prevalent reducing conditions in the landfill may cause reduction of nitrate to ammonia or to N_2, which results in a decrease in nitrate values and an increase in ammonia concentrations.

2.1 Effect of distance on groundwater contaminations

The extent of contamination level of groundwater quality due to leachate percolation depends upon a number of factors like chemical composition of leachate, rainfall, depth and distance of the well from the pollution source (the landfill site in the present case).

Groundwater samples of different depths and distances from landfill sites were analyzed in the present study to understand the level of combination (Mor et al., 2002). From the analysis, it is evident that the concentrations of contaminants were found to be high in the sampling sites which are near to the landfills. Interestingly, the groundwater contamination drops fast with increase in the distance of sampling sites from the landfill sites. The percolation of leachate was further found to become gentler. However, this aspect needs further investigations by drilling more wells of varying depths for having a proper correlation between distance and percolation depth.

Although, the concentrations of few contaminants did not exceed drinking water standard even then the groundwater quality represent a significant threat to public health. Strictly speaking one should avoid using groundwater drawn from the wells located in proximity of the waste dumping sites. If this is unavoidable, deeper drilling and frequent analysis of water samples are desirable. Efforts should be made to supply clean water through pipelines from distant sources.

2.2 Dissolved Organic Matter

Dissolved organic matter (DOM) is one of the matters that contains in MSW landfills leachate. DOM contains several major parameters such as TOC (Total Organic Carbon), COD (Chemical Oxygen Demand), and BOD (Biological Oxygen Demand). DOM has a significant biochemical and geochemical effect on landfills. DOM can interact with organic and inorganic contaminants therefore, some functional groups such as carboxylic, phenolic, and carbonyl in DOM cause interaction between DOM and other substances in the environment (Huo & Xi, 2008).

Natural soil usually has some amount of DOM and it depends on vegetation, soil type, clay mineralogy, metal oxides, and environmental factors such as temperature and rainfall. But penetrating leachate to the soil increases soil DOM and cause imbalances in the soil ecosystem. DOM is transported to watersources through the soil and affects water photochemistry, biological activity, pH of the water (Neina, 2019).

One of the important parameters of water quality is related to dissolved oxygen, which plays an important role in protecting fish and aquatic organisms. But dissolved oxygen in the water is affected by the entry of DOM because the decomposers decompose the organic matter by using oxygen. Therefore, increasing the amount of DOM penetrating into water sources reduces the amount of dissolved oxygen.This indicates that some materials that do not have specific pollutants, can have a detrimental effect on the environment according to the condition.

2.2.1. *Inorganic Macrocomponents*

Inorganic macrocomponents contain various ions such as calcium, magnesium, sodium, potassium, ammonium, iron, chloride, sulfate, nitrate, hydrogen carbonate and etc. Guide for industrial waste management (2003). The concentration of Inorganic macrocomponents in the leachate depends on the phases of the landfill stabilization. During methanogenic reactions, the pH is high and the concentration of calcium, magnesium, iron, and manganese decrease. Sulfate concentration reduces during methanogenic reactions due to microbial reduction of sulfate to sulfide. Ammonia is the most important component of the leachate. The source of ammonia in landfills is the decomposition of proteins, but there is no mechanism in landfills that can reduce the concentration of ammonia, and its concentration decreases only if it is discharged from the landfill through the leachate, otherwise, according to researches, the concentration of ammonia remains stable even 30 years after the closure of the landfill, that has very low inorganic content (Kjeldsen & Barlaz, 2002).

When the concentration of these ions in leachate and soil increases, it becomes harder for the roots of plants to get water from the soil because of osmotic pressure and cause reduce plant growth and damage vegetation. In addition, the presents of some ions such as sodium can significantly reduce the permeability of the soil. On the other hand, the high concentration of some specific ions can cause plant toxicity and contamination of groundwater (Guide for industrial waste management, 2003).

2.3 Heavy Metals

Heavy metal leachate is one of the most important contaminants of leachate. Heavy metals can pollute soil, groundwater, surface water, and also affect human health through mobility, solubility, and theability to transfer in water or plants (Naveen & Sumalatha, 2018). The main heavy metals in waste disposal leachate are cadmium, chromium, mercury, copper, zinc, lead, and arsenic (Chu et al., 2019). These heavy metals can be produced by disposing of various materials such as batteries, consumer electronics, ceramics, light bulbs, and glass in landfills. The use of heavy metals has increased over the years. Heavy metal concentration is usually high in the earlier phases of leachate production because more heavy metals dissolve in low pH as a result of organic acids (Naveen et al., 2018).

Food industry wastes are one of the most important materials disposed of in MSW landfills. Food wastes contain a variety of heavy materials in low concentrations, but some heavy metals are hazardous and seriously toxic even in low concentrations. For example, plastics used for food packing or other purposes mainly contain cadmium, chromium, and lead. These heavy metals cause serious toxicity on water and its impact on the aquatic ecosystem, food chain, and human health (Chu et al., 2019).

2.3.1 Xenobiotic Organic Compounds

Xenobiotic organic compounds contain monoaromatic hydrocarbons such as benzene, toluene, ethylbenzene, xylenes, and halogenated hydrocarbons such as tetrachloroethylene and trichloroethylene (Kjeldsen & Barlaz, 2002). These components are usually part of the household and industrial chemical wastes such as personal care products, pharmaceuticals, industrial, pesticides, and medicines wastes (Vodyanitskii, 2016). In addition, food additives such as stabilizers, antioxidants, pigments, as well as food packaging materials are another source of xenobiotic organic compounds in landfills **(**Neina, 2019).

Xenobiotic organic compounds have complex chemical structures and remain in the environment for a long time, therefore they have long-term effects on the environment, such as toxicity and biological accumulation in the cells of organisms. Xenobiotic organic compounds can enter the groundwater, surface water, or even agricultural soils. They affect aquatic life even in a short time. In addition, these compounds can reach the human food chain and cause various health problems. As their chemical structure is so stable in the environment, low concentrations of these compounds can be hazardous because they can accumulate and reach higher concentration and affect the environment.

These four groups of leachate contaminations that are generated in landfills show that the leachate has a wide range of components, each of which can have a negative impact on soil, groundwater, surface water, and the life of aquatic and animals. In some cases, they can enter the food chain and be hazardous for human health. as a result, these negative impacts continue for several years.

2.4 Concept of Sewage

Sewage are human and domestic waste matter from buildings, especially houses, that is carried away through sewers, it’s also a water-carried waste, in solution or suspension that is intended to be removed from a community. Also known as wastewater, it is more than 99% water and is characterized by volume or rate of flow, physical condition, chemical constituents and the bacteriological organisms that it contains. Classes of sewage include sanitary, commercial, industrial, agricultural and surface runoff. The wastewater from residences and institutions, carrying body wastes (primarily feces and urine) wash water, food preparation wastes, laundry wastes, and other waste products of normal living, are classed as domestic or sanitary sewage. Liquid-carried wastes from stores and service establishments serving the immediate community, termed commercial wastes, are included in the sanitary or domestic sewage category if their characteristics are similar to household flows. Wastes that result from and industrial processes such as the production or manufacture of goods are classed as industrial wastewater(McGraw-Hill, 2013).

2.4.1 Sewage Disposal

Sewage Disposal or wastewater disposal is the various processes involved in the collection, treatment, and sanitary disposal of liquid and water-carried wastes from households and industrial plants (Karadi, 2008).The predominant method of wastewater disposal in large cities and towns is discharge into a body of surface water. Suburban and rural areas rely more on subsurface disposal. In either case, wastewater must be purified or treated to some degree in order to protect both public health and water quality. Suspended particulates and biodegradable organics must be removed to varying extents. Pathogenic bacteria must be destroyed. It may also be necessary to remove nitrates and phosphates (plant nutrients) and to neutralize or remove industrial wastes and toxic chemicals Urban sewer mains generally discharge into interceptor sewers, which can then join to form a trunk line that discharges into the wastewater-treatment plant. Interceptors and trunk lines, generally made of brick or reinforced concrete, are sometimes large enough for a truck to pass through them.

2.4.2 Domestic Sewage

Domestic sewage originates primarily from kitchen, bathroom, and laundry sources, waste from food preparation, dishwashing, garbage-grinding, toilets, baths, showers, and sinks. Domestic sewage results from people's daily activities, such as bathing, body elimination, food preparation, and recreation, averaging about 227 liters (about 60 gallons) per person daily. Domestic sewage is also a major source of plant nutrients, mainly nitrates and phosphates. Excess nitrates and phosphates in water promote the growth of algae, sometimes causing unusually dense and rapid growths known as algal blooms.

2.4.3 Composition of Sewage

The composition of wastewater is analyzed using several physical, chemical, and biological measurements. The most common analyses include the measurements of solids, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and pH. The solid wastes include dissolved and suspended solids (DSS). Dissolved solids (DS) are the materials that will pass through a filter paper, and suspended solids (DS) are those that do not. Human and animal excreta (faeces, dung, urine, etc) contain a variety of pollutants inorganic, organic and microbiological, which can affect ground water quality adversely.

Human and animal waste loaded with microbiological pollutants may contain four types of pathogens (disease causing bacteria) like eggs of helminthes (worms), protozoa, bacteria and viruses. Human's faecal matter on an average contains 109 bacteria/gram (not of them pathogenic) and in case of infected person, faecal matter may contain as high as 106 viruses/gram.

2.4.4 Effects of water contaminated by sewage on human health

Shellfish strain water through their gills to trap microscopic plants and animals for food. If the water was contaminated with disease-causing bacteria, these could be consumed as food by shellfish. When eaten raw or partially cooked, these shellfish can make people sick. Certain fish in contaminated waters can accumulate high levels of toxic substances.

When these foods are consumed frequently over a lifetime, they may increase the consumer's risk of adverse health effects. Detergents can cause liver and kidney damage, while sewage water carries diseases like dysentery. Sewage is used water that often contains human waste (feces and urine). It is usually pumped through a network of pipes from homes and businesses to a sewage treatment plant. Sometimes large sewage lines break and the contents leak into marine recreational waters and beaches. What organisms can live in sewage-contaminated water a variety of organisms live in the human gastrointestinal tract, these organisms, including bacteria, viruses, and parasites, end up in human waste. Many of these organisms can be transmitted to other humans and animals, including marine organisms like shellfish, through contact with sewage-contaminated water. Hepatitis can look exactly like gastro-enteritis. Severe cases cause people's skin to become yellow, or jaundiced, because the liver is not able to clear out its own bile. Bile contains the liver's waste products.

2.5 Water

Water, common name applied to the liquid state of the hydrogen-oxygen compound (H_2O). The ancient philosophers regarded water as a basic element typifying all liquid substances. An excellent natural resource in the entire ecosystem, the critical bond to all spheres, it can be made to serve various functions such as domestic, industrial, agricultural, transportation and other uses. Man cannot survive very long without water neither can plant or animals live without water.

2.5.1 Microbiological aspect of water

Ideally, drinking water should not contain any micro-organism known to be pathogenic. Water microbiology is usually done to test the bacterial load in water sample, which are present in water sources such as underground water such as well and boreholes (WHO, 1985). In safeguarding public water supply, health authorities and water engineers rely on information obtained from results of frequent bacteriological tests. The demonstration of pathogenic material such as typhoid bacilli would obviously constitutes the most direct proof of dangerous impurities. The pathogens, if present are usually so scanty that technical difficulties of their isolation make it impracticable for ordinary purpose. Instead the test that will remove the process of commercial bacterial of intestinal organs like those of coliform group is usually used.

2.5.2 Control of Bacteria

All bacteria require certain condition to live. Knowledge of such condition enable us to kill the bacteria, by making the condition impossible to for them to live. The living conditions of bacteria are light, temperature, oxygen, water (Sadat et al., 2017). Different species of bacteria have different ideal temperature requirement. Soil bacteria are most active at 300C while activity stops at 00C for most bacteria. Boiling kills many bacteria but not spores.

2.6 Importance of access to safe drinking water

According to the World Health Organization, "access to safe drinking-water is essential to health, a basic human right and a component of effective policy for health protection. The amount of drinking water required is variable. It depends on physical activity, age, health, and environmental conditions (Ann, 2004).In a temperate climate under normal conditions, adequate water intake is about 2.7 litres (95 imp fl oz; 91 US fl oz) for adult women and 3.7 litres (130 imp fl oz; 130 US fl oz) for adult men (*US Institute of Medicine, Food and Nutrition Board*, 2004). Physical exercise and heat exposure cause loss of water and therefore may induce thirst and greater water intake. Physically active individuals in hot climates may have total daily water needs of 6 litres (210 imp fl oz; 200 US fl oz) or more (*US Institute of Medicine, Food and Nutrition Board*, 2004). The recommends 2.0 litres (70 imp fl oz; 68 US fl oz) per day for adult women and 2.5 litres (88 imp fl oz; 85 US fl oz) per day for adult men (*EFSA Panel on Dietetic Products, Nutrition, and Allergies*, 2010).

In the United States, the (RDI) for total water is 3.7 litres (130 imp fl oz; 130 US fl oz) per day for human males older than 18, and 2.7 litres (0.59 imp gal; 0.71 US gal) per day for human females older than 18 which includes drinking water, water in beverages, and water contained in food. An individual's thirst provides a better guide for how much water they require rather than a specific, fixed quantity.

Americans, on average, drink one litre (35 imp fl oz; 34 US fl oz) of water a day and 95% drink less than three litres (110 imp fl oz; 100 US fl oz) per day.

Water makes up about 60% of the body weight in men and 55% of weight in women. A baby is composed of about 70% to 80% water while the elderly are composed of around 45%.

The drinking water contribution to mineral nutrients intake is also unclear. minerals generally enter surface water and ground water via or through the Earth's crust. Treatment processes also lead to the presence of some minerals. Examples include, and compounds. Water generated from theof nutrients provides a significant proportion of the daily water requirements for some and animals, but provides only a small fraction of a human's necessary intake. There are a variety of trace elements present in virtually all potable water, some of which play a role in metabolism. For example, sodium, and are common chemicals found in small quantities in most waters, and these elements play a role in body metabolism. Other elements while beneficial in low concentrations, can cause dental problems and other issues when present at high levels.

2.7 Quality of Water

Water quality refers to the chemical, physical, biological, and radiological characteristics of water.It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose (Diersing, 2009). It is most frequently used by reference to a set of standards against which compliance can be assessed. The most common standards used to assess water quality relate to health of ecosystems, safety of human contact and drinking water (Johnson et al., 1997).

The water quality of rivers and lakes changes with the seasons and geographic areas, even when there is no pollution present. There is no single measure that constitutes good water quality. For instance, water suitable for drinking can be used for irrigation, but water used for irrigation may not meet drinking water guidelines. The quality of water appropriate for recreational purposes differs from that used for industrial processes.

2.7.1 Water quality standards

Although pure water is rarely found in nature (because of the strong tendency of water to dissolve other substances), the characterization of water quality (i.e., clean or polluted) is a function of the intended use of the water. For example, water that is clean enough for swimming and fishing may not be clean enough for drinking and cooking. Water quality standards (limits on the amount of impurities allowed in water intended for a particular use) provide a legal framework for the prevention of water pollution of all types.

2.7.2 Factors that Influence Water Quality

Many factors affect water quality. The natural water quality of groundwater in aquifers is related to the quality of recharge water, the mineralogy of soils and aquifer sediments, and the residence time in the ground water flow system, and the presence of nearby saline water. However, the primary influence on groundwater quality (as well as surface water quality) is the contamination brought about by human activity (IFAS Extension, 2007). Urban storm water, agricultural runoff, domestic wastewater, industrial wastewater, and hydrologic modifications are the major sources of water pollution.

2.7.3 Measurement of Water Quality

The quality of water is determined by making measurements in the field or by taking samples of water, suspended materials, bottom sediment, or biota, and sending them to a laboratory for physical, chemical and microbiological analyses. For example, acidity (pH), color and turbidity (a measure of the suspended particles in the water) can be measured in the field. The concentrations of metals, nutrients, pesticides and other substances are measured in the laboratory. Another way to obtain an indication of the quality of water is biological testing. This test determines, for example, whether the water or the sediment is toxic to life forms or if there has been a fluctuation in the numbers and kinds of plants and animals.

2.7.4 Quality of Drinking Water

Good quality drinking water is free from disease-causing organisms, harmful chemical substances, and radioactive matter. It tastes good, is aesthetically appealing, and free from objectionable color or odor (WHO,2022). It should be noted that there is a difference between "pure water" and "safe drinking water". Pure water, often defined as water containing no minerals or chemicals, does not exist naturally in the environment. Under ideal conditions, water may be distilled to produce "pure" water. Safe drinking water, on the other hand, may retain naturally occurring minerals and chemicals such as calcium, potassium, sodium or fluoride which are actually beneficial to human health and may also improve the taste of the water. Where the minerals or chemicals occur naturally in concentrations that may be harmful or displeasing, then certain water treatment processes are used to reduce or remove the substances. In fact, some chemicals are actually added to produce good drinking water; the best examples of chemical addition are chlorine used as a disinfectant to destroy microbial contaminants.

2.8 Water Pollution

Water Pollution is the contamination of streams, lakes, underground water, bays, or oceans by substances harmful to living things, water is necessary to life on earth. All organisms contain some live in it, some drink it. Plants and animals require water that is moderately pure, and they cannot survive if their water is loaded with toxic chemicals or harmful microorganisms. Pollution makes streams, lakes, and coastal waters unpleasant to look at, to smell, and to swim in. Fish and shellfish harvested from polluted waters may be unsafe to eat. People who ingest polluted water can become ill, and, with prolonged exposure, may develop cancers or bear children with birth defects. The major water pollutants are chemical, biological, or physical materials that degrade water quality. Pollutants can be classed into two categories, each of which presents its own set of hazards.

2.8.1 Sources of Water Pollution

Water pollutants come from either point sources or dispersed sources. A point source is a pipe or channel, such as those used for discharge from an industrial facility or a city sewerage system. A dispersed (or nonpoint) source is a very broad, unconfined area from which a variety of pollutants enter the water body, such as the runoff from an agricultural area. Point sources of water pollution are easier to control than dispersed sources because the contaminated water has been collected and conveyed to one single point where it can be treated. Pollution from dispersed sources is difficult to control, and, despite much progress in the building of modern sewage-treatment plants, dispersed sources continue to cause a large fraction of water pollution problems.

2.8.1.1 Point-sources

Point source water pollution refers to contaminants that enter a waterway from a single, identifiable source, such as a pipe or ditch. Examples of sources in this category include discharges from a sewage treatment plant, a factory, or a city storm drain. Include municipal storm sewer systems, as well as industrial storm water, such as from construction sites.

2.8.1.2 Non-point sources

Non-point source pollution refers to diffuse contamination that does not originate from a single discrete source. Non-Point Source pollution is often the cumulative effect of small amounts of contaminants gathered from a large area. A common example is the leaching out of nitrogen compounds from fertilized agricultural lands. Nutrient runoff in storm water from "sheet flow" over an agricultural field or forest, are also cited as examples of Non-Point Source pollution.

2.9 Groundwater

The term groundwater refers to all water which is below the surface of the ground in the saturated zone and which is in direct contact with the ground or subsoil. The saturated zone is where all the cracks in the rock and all the spaces between the grains of rock or within the soil are filled with water. The upper limit of the saturated zone may be thought of as the water table, the zone above the water table, where pore spaces contain both air and water, is known as the unsaturated zone.

Furthermore, groundwater is water contained in underground geologic formations called aquifers, is a source of drinking water for many people. For example, about half the people in the United States depend on groundwater for their domestic water supply. Although groundwater may appear crystal clear (due to the natural filtration that occurs as it flows slowly through layers of soil), it may still be polluted by dissolved chemicals and by bacteria and viruses.

2.9.1 Groundwater Pollution

Interactions between groundwater and surface water are complex. Consequently, groundwater pollution, sometimes referred to as groundwater contamination, is not as easily classified as surface water pollution (USGS, 1998). By its very nature, groundwater aquifers are susceptible to contamination from sources that may not directly affect surface water bodies, and the distinction of point with nonpoint source may be irrelevant. A spill or ongoing releases of chemical or radionuclide contaminants into soil (located away from a surface water body) may not create point source or non-point source pollution, but can contaminate the aquifer below defined as a toxin plume. The movement of the plume, called a plume front, may be analyzed through a hydrological transport model or groundwater model. Analysis of groundwater contamination may focus on the soil characteristics and geology, hydrogeology, hydrology, and the nature of the contaminant.

2.9.2 Causes of Groundwater Pollution

The specific contaminants leading to pollution in water include a wide spectrum of chemicals, pathogens, and physical changes such as elevated temperature and discoloration. While many of the chemicals and substances that are regulated may be naturally occurring (calcium, sodium, iron, manganese, etc.) the concentration is often the key in determining what is a natural component of water, and what is a contaminant. High concentrations of naturally occurring substances can have negative impacts on aquatic flora and fauna. Oxygen-depleting substances may be natural materials, such as plant matter (e.g. leaves and grass) as well as man-made chemicals. Other natural and anthropogenic substances may cause turbidity (cloudiness) which blocks light and disrupts plant growth, and clogs the gills of some fish species (EPA, 2005).

2.9.3 Effects of Groundwater Pollution

When toxic substances enter a body of water, they will be dissolved, become suspended in water or get deposited on the bed of the water body. The resulting water pollution causes the quality of the water to deteriorate and affects aquatic ecosystems. Pollutants can also seep down and effect groundwater deposits. Sewage and industrial wastes are discharged into the rivers. Because of this, pollutants enter groundwater, rivers, and other water bodies. Such water, which ultimately ends up in our households, is often highly contaminated and can carry disease-causing microbes.

2.10 Review of Empirical Studies

Also, Peter et al (2007), evaluated the chemical quality of drinking water in Cambodia. They noted in their studies that there are several water parameters that are of health and aesthetic concern, and the most significant parameter in water sampled is dissolved arsenic. In aquifers of moderate depth in several highly populated areas, high arsenic levels were detected, confirming presence of chemical pollutants. The groundwater sources in this area are negatively impacted by parameters of aesthetic concern, such as iron, manganese, hardness and total dissolved solids, and the consumer preferred the surface water sources to the newly installed water supplies as a result of the presence of these parameters in the water.

Again, Kehinde et al. (2021) examined the physico-chemical characteristics of groundwater inOndo City, Nigeria, using 32 water samples. He used Principal component and Cluster analysis to characterize groundwater quality in the areas. The result shows that the groundwater in the region is acidic, which is an evidence of infiltration of waste from industries into the groundwater zone as well as the intrusion of sea water. He suggested that government and non-governmental organization should ensure that the groundwater of the area is protected from pollution by taking required steps.

In addition, Digha and Ekanem (2015) studied the effects of Population Density on groundwater quality in Calabar Municipality, Nigeria, using a total of six (6) groundwater samples. The results show the following range and mean value; temperature (28.5-30°C) with a mean value of 29.5°C, pH (6.0- 6.3) with a mean value of 6.05, indicating that groundwater in the area is slightly acidic, EC (95.2-296IJS/cm) with a mean value of 171.1IJS/cm, TDS (47.6-148mg/l) with an average value of 85.4mg/l, Ca (0.8-1.8mg/l) with a mean value of 1.1 mg/l, CI (6-10 mg/l) with a mean value of 7.8mg/l and faecal coliform (0-19 CFU/100) with a mean value of 8.8CFU/1 00. Their result indicated that the groundwater quality around the study area is suitable for irrigation while groundwater around Ediba, Essien Town, Ikot Omin and Ikot Effanga is not fit for drinking, due to high content of coliform bacteria. Therefore, groundwater in these areas should be treated before drinking.

Udoka (2008) examined the physico-chemical and bacteriological properties of boreholes in seven Local Government Areas of Anambra State, to ascertain their portability and evaluate the seasonal variation in the population levels of the borehole water and a total of 42 boreholes were sampled. The membrane filtration method was used to estimate the total coliforms, faecal coliforms and enterocci counts while the atomic absorption spectrophotometer was used to determine the minerals elements. The average total of coliforms, faecal coliforms, and enterococci counts of the borehole water samples in each of the seven local government areas covered were above the World Health Organization (WHO 2006) permissible limit for drinking water source. While the values of the physico–chemical parameters such as nitrate (0.025 – 0.19mg/1), total solids (60 – 180mg/1), pH (6.5–6.80), fall within the World Health Organization (WHO) permissible limit for drinking water but the value of Iron were relatively high. However, he suggested that water should be treated properly before consumption.

III. MATERIALS AND METHOD

3.1 Materials and Methods

3.1.1 Physical Analysis

General appearance

Determination of General Physical Appearance

Method: Visible Characteristics detection by the unaided eye.

Apparatus: The Unaided eye (Human eye only)

Procedure:

i. Carefully observed the general physical appearance of the water sample.
ii. Checked for visible characteristics that my hinder the aesthetic value and acceptability profile of the water sample.
iii. Used appropriated terms to briefly describe presence of color, turbidity, suspended solids, organisms, sitt, sediments, floating material, similar particulate matter.

Turbidity

Method: Nephelometric method

Apparatus: Digital Turbidity meter, glass wares.

Procedure:

i. The water sample was measured into a glass beaker
ii. Distilled water sample was measured out. This should serve as blank.
iii. The blank was first measured and noted.
iv. Then the water sample was measured and recorded accordingly.

Taste

Determination of Taste

Method: Organoleptic method

Apparatus: Human organs of taste (mouth and tongue) glass wares

Procedure:

i. The water sample was mixed properly by shaking
ii. A portion of the water sample was used to rinse the glass wares.
iii. Another portion of the sample was measured out and poured into a glass wares.
iv. This portion was drank and swallowed.

Temperature

Determination of Temperature

Method: Temperature was measured using a thermometer.

Apparatus: Thermometer, Glass wares

Procedure:

i. The thermometer was rinsed with distilled water and blotted dry.
ii. The thermometer was the rinsed in a small beaker with a portion of the sample
iii. Sufficient amount of the sample was poured into a beaker
iv. The thermometer was immersed into the beaker containing the amount of the sample to be measured.
v. The temperature reading of the sample indicated on the thermometer was read off and recorded accordingly

Odour

Determination of Odour

Method: Organoleptic Method

Apparatus: The human nose and glass wares

Procedure:

i. The water sample was mixed properly by shaking
ii. A portion of the water sample was used to rinse the glass wares
iii. Another portion of the sample was measured out and poured into an open glass wares (100ml beaker) container.
iv. This open container containing a portion of the sample was brought very close to the nose to check for odour.
v. The result was recorded.

Electrical conductivity

Determination of electrical conductivity

Method: Conductivity was measured using a conductivity meter.

Apparatus:

Conductivity meter, glass wares

Procedure:

i. The conductivity meter was rinsed with distilled water and blotted dry. The conductivity meters probe was then wetted thoroughly by immersing it or rinsing it with a portion of the sample.
ii. The sample was mixed and sufficient (50ml) amount of the sample was then poured into a 100 beaker.
iii. The conductivity meter's wetted probe was then immersed in the glass beaker containing the sample to be measured.
iv. The conductivity meter switched on and the reading taken and recorded.

Total Dissolved Solid (TDS)

Determination of Total Dissolved Solids

Method: Total Dissolved Solids dried at 180^0C

Apparatus: Evaporating dishes (porcelain, 90mm diameter), Drying Oven, Glass-Fiber filter disks, filtration apparatus, Desiccator, Analytical balance, Magnetic stirrer with TFE stirring bar.

Procedure:

A well- mixed sample is filtered through a standard glass fiber filter, and the filtrate is evaporated to dryness in a weighed dish and dried to constant weight at 180^0 C. The increase in dish weight represents the total dissolved solids.

3.1.2 Chemical Analysis

pH

Determination of pH

Method: pH was measured by electrometric method using laboratory pH Meter Hanna Model H1991300 (APHA; 1998), 100m Beaker.

Procedure:

i. The electrodes were rinsed with distilled water and blotted dry.
ii. The pH electrodes were then rinsed in a small beaker with a portion of the sample.
iii. Sufficient amount 50ml of the sample was poured into small beaker (100ml beaker) allow the tip of the electrodes to be immersed to the mark depth of about 2cm, the electrodes were at least 1cm away from the sides and bottom of the beaker.
iv. The temperature adjustment dial was adjusted accordingly
v. The pH meter was turned on and the pH of the sample recorded.

Total Alkalinity

Determination of Total Alkalinity

Method: Total Alkalinity (Titremetric Method)

Apparatus: Titration apparatus, 0.02NH_2SO_4 Acid, Methyl Orange indicator, Glass wares.

Procedure:

All glass wares were pre-washed and rinsed with the expected solution it will contain in the course of the procedure. 100ml of sample was dispensed into a 250ml Erlenmeyer (conical) flask.

Three (3) drops of methyl orange indicator solution or a pinch of the powder was added to the solution and it turned yellow. Carefully, titration against 0.02N of H_2SO_4 was done until an end point of orange red colour appearance. The volume of 0.02N H2SO4 solution used was noted and served as the titre value.

The total alkalinity in mg/l $caco_3$ was calculated:

$$\text{Mg/l } CaCo_3 = \frac{N \times T \times 50000}{\text{Vol.of sample used}}$$

Where, N = Normality of Acid

T = Tire value

Iron

Determination of Iron

Method: Atomic absorption spectrophotometer

Apparatus: Flame Aspiration Atomic Absorption Spectrophotometer water 100ml sample beaker, glass wares.

Procedure:

i. Mix sample thoroughly by shaking
ii. Measures out 100ml aid pour into a 100ml beaker.0

3.2 Methods of Data Analysis

The data analysis commenced with simple statistical measure of the mean and standard deviations of the variables; after which, comparative t-test statistical estimation was performed.

The test statistic for the t-test follows the formula specified in Spiegel (1974) as;

$$t = \frac{\bar{X} - U}{S}\sqrt{N-1} \qquad \text{Equation 3.1}$$

Where; $\bar{X}$ is the obtained mean for each parameter

U is the World Health Organisation's (WHO) or Nigeria Standard of Drinking Water Quality (NSDWQ) limiting value,

S is the standard deviation of the water samples for each parameter extracted from the water sample.

N is the total number of cases observed in the field which is twenty in this study.

EXPERIMENTAL PROCEDURES/WATER ANALYSIS

The following procedures were carried out during the characterization process

DETERMINATION OF TOTAL ACIDITY

- Procedure:

a) Pipette 10ml of water sample into a conical flask

b) Add three (3) drops of phenolphthalein

c) Titrate with 0.1N NaOH solution

- Observation: The solution turns Pink (red)

- Calculation:

$$\boldsymbol{Total\ acidity} = \frac{Tv \times N \times 50 \times 1000}{Volume\ of\ sample}\left(\frac{mg}{l}\right)$$

N.B: N = normality of NaOH

DETERMINATION OF TOTAL ALKALINITY

- Procedure:

a) Pipette 10ml of water sample into a conical flask

b) Add three (3) drops of methyl orange indicator

c) Titrate with 0.1N HCl

- Observation: Yellow colour changes to orange

- Calculation:

$$\text{Total Alkalinity} = \frac{Tv \times N \times 50 \times 1000}{Volume\ of\ sample}\left(\frac{mg}{l}\right)$$

Where N = normality of the HCl

DETERMINATION OF DISSOLVED SOLIDS/ SUSPENDED SOLIDS

- Procedure:

a) 50g of each of the water sample was weighed

b) Two (2) filter papers were weighed each for one sample

c) The samples were filtered into 100ml beakers that had already been weighed

d) The filter paper and solids were dried at 103^0C to 105^0C to a constant weight for blank, filter approximately 50g of distilled water and dry it as the sample.

- Calculation:

Total suspended solid$\left(\frac{mg}{l}\right) = \frac{(A-B-C) \times 1000}{Volume\ of\ sample}$

Where; A = weight of filter paper and solids, gram

B = weight of filter paper, gram

C= blank correction, grams = (final weight of blank filter paper) – (initial weight of blank filter paper)

After the filtration, the undissolved solids were trapped by the filter papers. The filter papers were then dried in the oven and reweighed after cooling. The filtrates in the beakers were evaporated on a hot plate. They were also cooled and reweighed.

DETERMINATION OF CHLORIDE

- Procedure:

a) 50ml of each of the water sample was measured into 250ml conical flask respectively.

b) The pH of the water sample is adjusted from 6·00 to 8·50 with sodium bicarbonate or nitric acid. (The pH adjustment is necessary if the pH of the water is acidic).

c) Add two (2) drops of 0·1m potassium chromate indicator into each of the sample in the conical flask.

d) The samples were then titrated with a standard 0·1N silver nitrate in the burette. End point is reached when a brick-red color persists.

- Calculation:$\boldsymbol{Chloride = \frac{Tv \times N \times 35{\cdot}5 \times 1000}{Volume\ of\ sample}}$

IV. DATA ANALYSIS AND INTERPRETATION OF RESULTS

The data presentation was done in the form of presenting and discussing the raw table from the laboratory analysis of the samples. The raw data was subjected to the student's t-test.

4.1 Analysis of the Physical Parameters from the Groundwater

TEMPERATURE

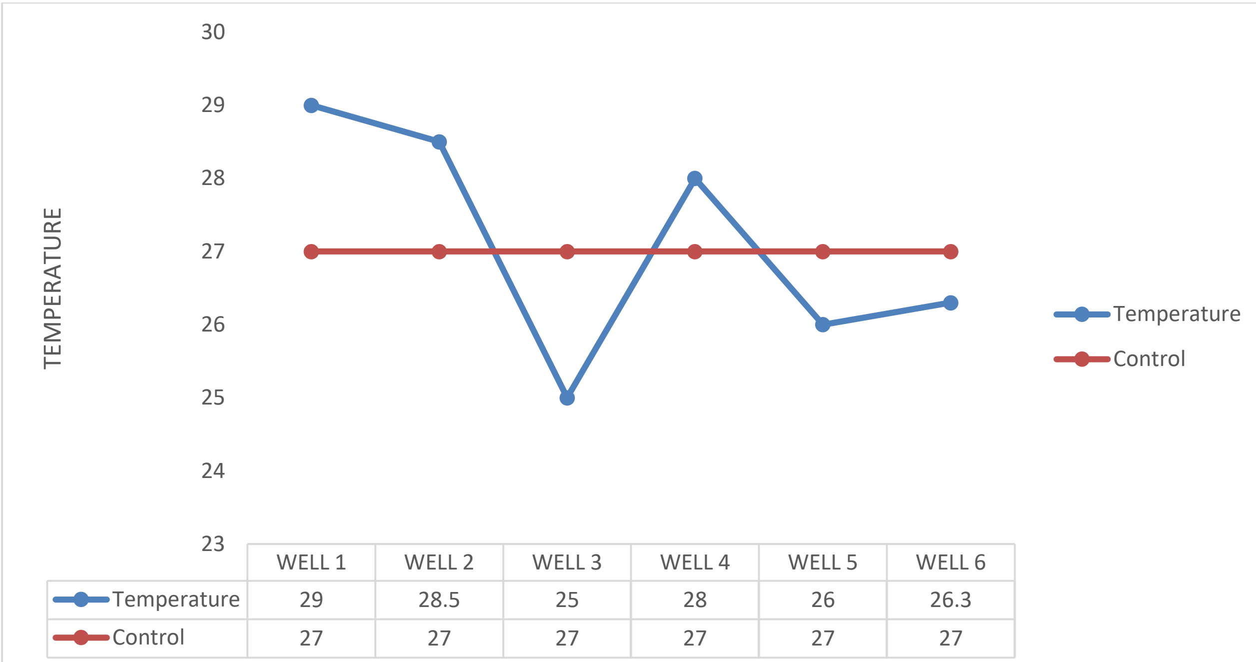

Fig 1: Line plot of Temperatur vs Standards

Fig 1 is the line plot of wells when considering the borehole control for the temperature. From the plot, it suggest that there is a better comaparison between the wells and borehole control (as the standard) since there is no much wide gap between the wells when considering temperature as the parameter for grounwater.

Table 4.1: Summary table for mean, normality and one sample t-test for Temperature of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	27.1333	1.58955	.64893		
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig	Statistic	df	Sig
	Well	.207	6	.200	.928	6	.564
One-Sample Test							
		t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Borehole Control (27)	Well	.205	5	.845	.13333	-1.5348	1.8015
WHO	Well	====	====	====	====	====	====

Source: Researcher's extract from SPSS 25.0

Table 4.1 is the summary table for mean, normality and one sample t-test for temperature of groundwater; the results of the sample t-test was used to see if the different samples for temperature of groundwater differed significantly from the standard control which was defined as the (borehole control). According to the Shapiro Wilk's Test (P>0.05), the sample scores were normally distributed, and there were no outliers in the data.

The mean of the samples for temperature is (**27.13333** ± 1.58955), which is higher than the standard mean (Borehole control), but not statistically significant by 0.13333 (95% CI, -1.5348 to 1.8015, $t(5) = 0.205$, $p = 0.845 > 0.05$. Since the temperature of the groundwater samples is above the critical temperature of 25˚C, it shows that the water is polluted and therefore not good for drinking.

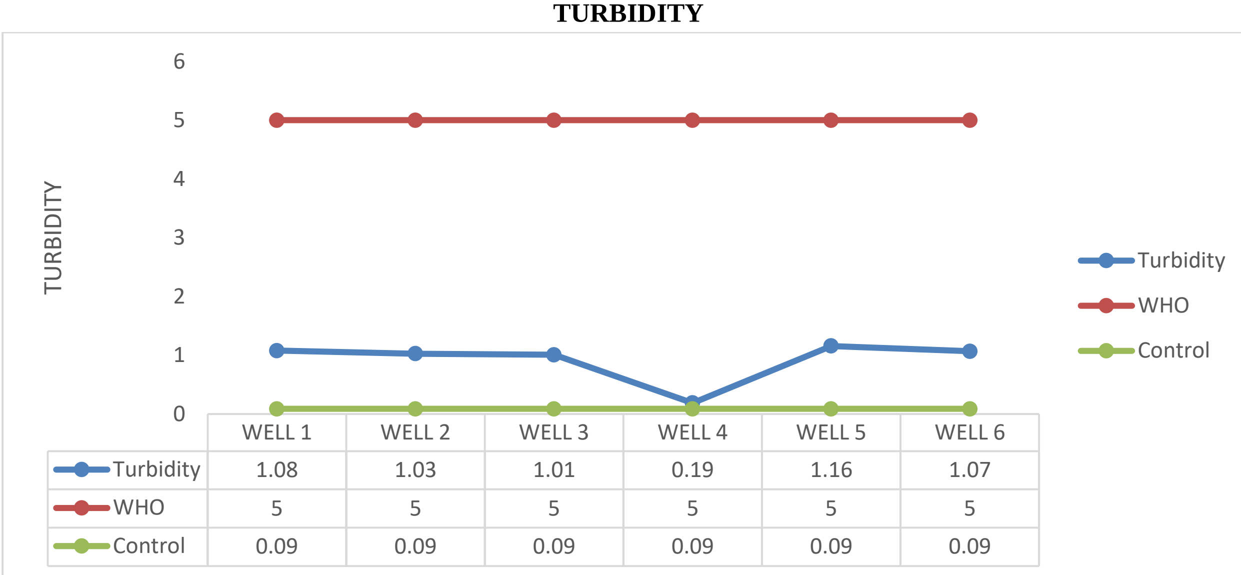

Fig 2: Line plot of Turbidity vs Standards

Fig 2 is the line plot of wells when considering the borehole control as Standard for the turbidity. From the plot, it suggest that a better comaparison would be between the wells and borehole control (as the standard) since there is wide gap between the WHO standard and the wells when considering turbidity as the parameter of groundwater.

Table 4.2: Summary table for mean, normality and one sample t-test for Turbidity of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	.9233	.36297	.14818		
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig	Statistic	df	Sig
	Well	.503	6	.067	.459	6	.052
One-Sample Test							
		t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Borehole Control (0.09)	Well	5.624	5	.002	.83333	.4524	1.2142
WHO (5)	Well	-27.511	5	.000	-4.07667	-4.4576	-3.6958

Source: Researcher's extract from SPSS 25.0

The results of the sample t-test were used to check if the different samples for turbidity of groundwater differed substantially from the standard control, which was defined as (borehole control / WHO). The mean, normality, and one sample t-test for turbidity of groundwater is represented in Table 4.2 above. The sample scores were normally distributed, with no outliers in the data, according to the Shapiro Wilk's Test (P>0.05).

The mean of the samples for turbidity is (**0.9233** ± 0.36297), which is higher and statistically significant in comparison with the standard borehole control (0.09), by 0.83333 (95% CI, 0.4524 to 1.2142), t(5) = 5.624, p =0.002<0.05. Similarly, it is also significant when compared with the WHO standard by -4.07667 (95% CI, -4.4576 to -3.6958),t(5) = -27.511, p =0.000<0.05. Turbidity describes the optical property of the water samples. It shows the ability of light to pass through the water. The higher the volume of suspended particles, the cloudier the water becomes. The WHO specification is that the turbidity of a drinking water should not exceed 5NTU (mg/l) while our control specifies 0.09NTU (mg/l). Result of this study shows that the Turbidity lies between 0.19NTU and 1.16NTU. The values are within the WHO standard limit. But for people within the vicinity, it shows that the water is not drinkable as the values are above control sample specification. Also, based on literature, turbidity condition increases the possibility of waterborne disease (Postolache et al., 2012). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.

Taste, Odour and Colour

The water is tasteless, odourless and colourless.

CONDUCTIVITY

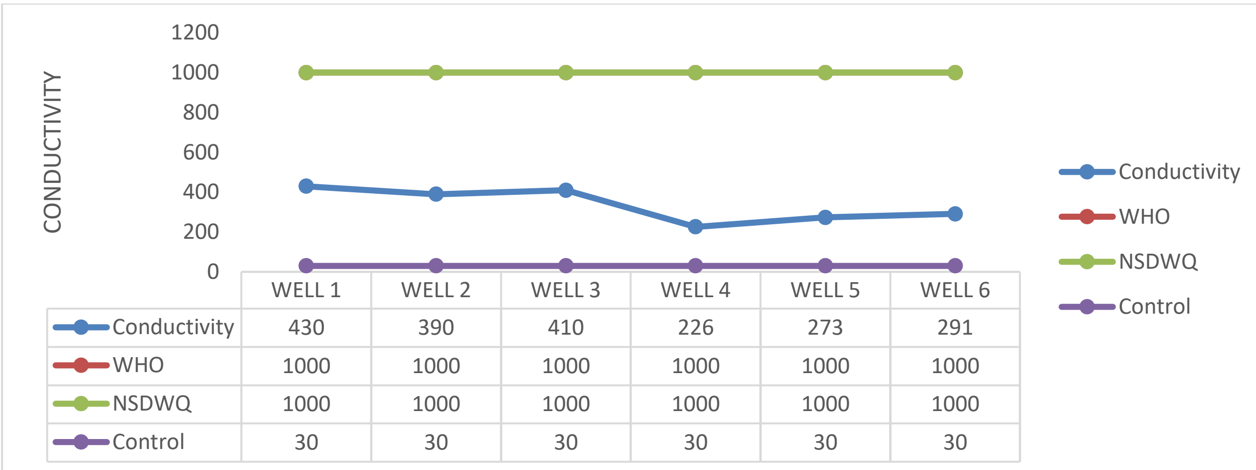

Fig 3: Line plot of conductivity vs Standard

Fig 3 is the line plot of wells when considering the borehole control, NSDWQ and the WHO Standard for the Conductivity. From the plot, its obvious there is wide gap between the wells and all the standard employed when considering conductivity as parameter of groundwater.

Table 4.3: Summary table for mean, normality and one sample t-test for Conductivity of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	336.6667	84.04681	34.31197		
		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
		Statistic	**df**	**Sig**	**Statistic**	**df**	**Sig**
	Well	.205	6	.200	.934	6	.589
One-Sample Test							
		t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	**Upper**
Borehole Control (30)	Well	8.938	5	.000	306.66667	218.4649	394.8684
WHO (1000)	Well	-19.332	5	.000	-663.33333	-751.5351	-575.1316

Source: Researcher's extract from SPSS 25.0

The sample t-test findings were used to see if the conductivity of groundwater samples differed significantly from the standard control, which was specified as (borehole control / WHO). Table 4.3 above shows the mean, normality, and one-sample t-test for groundwater of conductivity. According to the Shapiro Wilk's Test (P>0.05), the sample scores were normally distributed with no outliers in the data.

The mean of the samples for conductivity is (**336.6667** ± 84.04681), which is higher than the standard mean (Borehole control) but below the WHO permissible standard, is statistically significant by 306.66667 for (Borehole 95% CI, 218.4649 to 394.8684; t(5) = 8.938, p = 0.000); and -663.33333 for (WHO 95% CI, -751.5351 to -575.5351; t(5) = -19.332, p =0.000).

Generally, conductivity otherwise known as electrical conductivity indicates the presence of ion in the water samples. This is usually as a result of saline water. The conductivity values from the study samples are between 226 mg/l and 430 mg/l with average value of 307.79 mg/l. These values are substantially above the control value of 30mg/l. The indication is that there is low concentration of dissolved ions in the water. Not minding that, the water not is drinkable in the vicinity since the values are above the control value of 30mg/l.

TOTAL SOLID

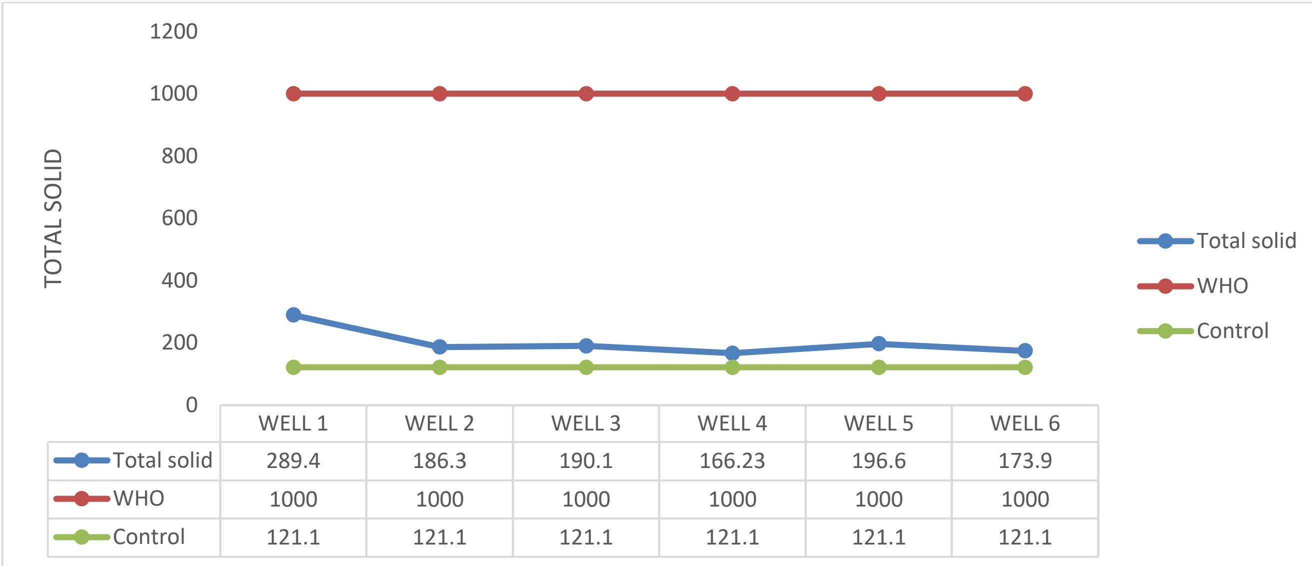

Fig 4: Line plot for Total solid vs Standard

Fig 4 is the line plot of wells when considering the borehole control and WHO as the standard for the Total solid. From the plot sample control comaprison with the samples i.e (well 1 to well 6). It is obvious that for the wells there is a close similarities between them and the borehole control which is the standard for total solid. However, there is a wide gap between the WHO standard and that of the wells for total solid of ground water.

Table 4.4: Summary table for mean, normality test and one sample t-test for Total Solid of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	191.01143	48.009347	18.145828		
		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
		Statistic	**df**	**Sig**	**Statistic**	**df**	**Sig**
	Well	.311	6	.040	.843	6	.106
One-Sample Test							
		t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	Upper
Borehole Control (121.1)	Well	3.853	5	.008	69.911429	25.51019	114.31267
WHO (1000)	Well	-44.583	5	.000	-808.988571	-853.38981	-764.58733

Source: Researcher's extract from SPSS 25.0

In table 4.4; a one sample t test was used to see if the different samples for total solid differed from the standard control which was defined as the borehole control of 69.911429. According to Shapiro Wilk's Test (P>0.05), the sample scores were normally distributed, and there were no outliers in the data.

The mean of the samples for total solid is (**191.01143** ± 48.009347), which is higher than the standard mean (Borehole control), is statistically significant by 69.911429 (95% CI, 25.51019 to 114.31267), t(5) = 3.853, p =0.008. Similarly, when using WHO as the standard, it is obvious from the results that it is equally statistically significant at 5% level of significance giving by −808.988571 (95% CI, -853.38981 to -764.58733).

The value of our total solids which a lumpsum of the total dissolved and total suspended solids lies between 166.23 to 289.4 with average value of 191.01. The control value is 121.1 while the WHO permissible standard is 1000.

TOTAL DISSOLVED SOLID

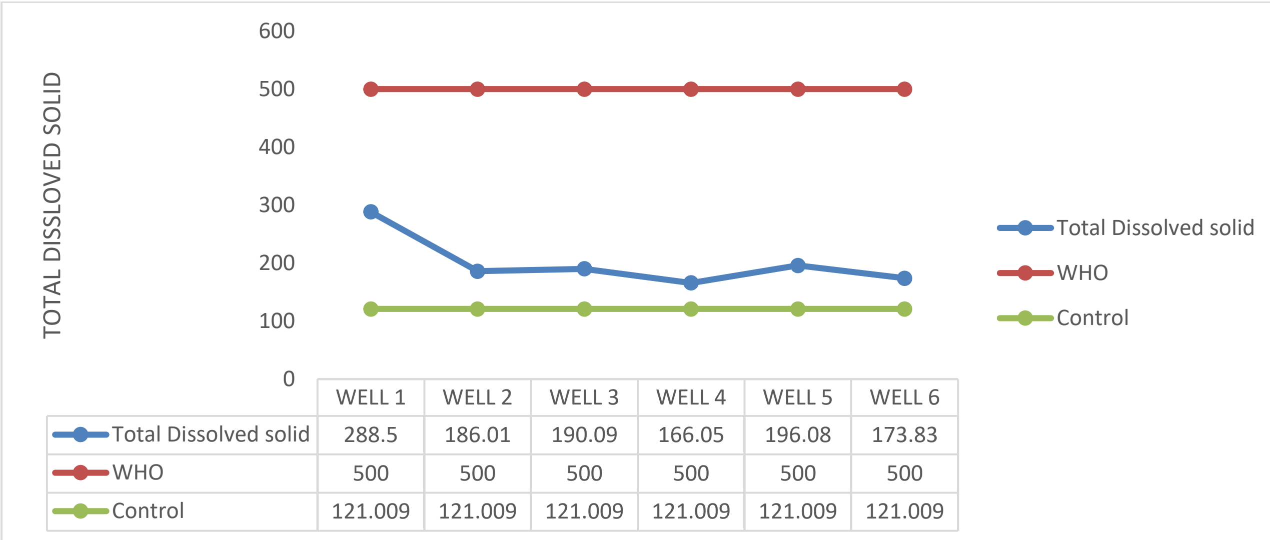

Fig 5: Line plot Total dissolved vs Standards

Fig 5 is the line plot of wells when considering the borehole control and the WHO Standard for the Total dissolved. From the plot its obvious there is wide gap between each of the wells and all the standard employed when considering total dissolved as parameter of ground water.

Table 4.5: Summary table for mean, normality and one sample t-test for Total dissolved of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	190.73000	47.716503	18.035143		
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig	Statistic	df	Sig
	Well	.313	6	.037	.843	6	.106
One-Sample Test							
		t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Borehole Control (121.009)	Well	3.866	5	.008	69.721000	25.59059	113.85141
WHO (500)	Well	-17.148	5	.000	-309.27000	-353.40041	-265.13959

Source: Researcher's extract from SPSS 25.0

Table 4.5 is the summary table for mean, normality and one sample t-test for total dissolved solid of groundwater; the results of the sample t-test was used to see if the different samples for total dissolved solid of groundwater differed significantly from the standard control which was defined as the (borehole control). According to the Shapiro Wilk's Test ($P>0.05$), the sample scores were normally distributed, and there were no outliers in the data.

The mean of the samples for total dissolved solid is (**190.73000** ± 47.16503), which is lower than the standard mean (Borehole control / WHO Standard), is statistically significant by 69.721000 (95% CI 25.59059 to 113.85141), $t(5) = -3.866$, $p < 0.05$ and -309.27000 (95% CI, -792.34037 to -592.07392), $t(5) = -17.148$, $p < 0.001$ respectively.

TOTAL SUSPENDED

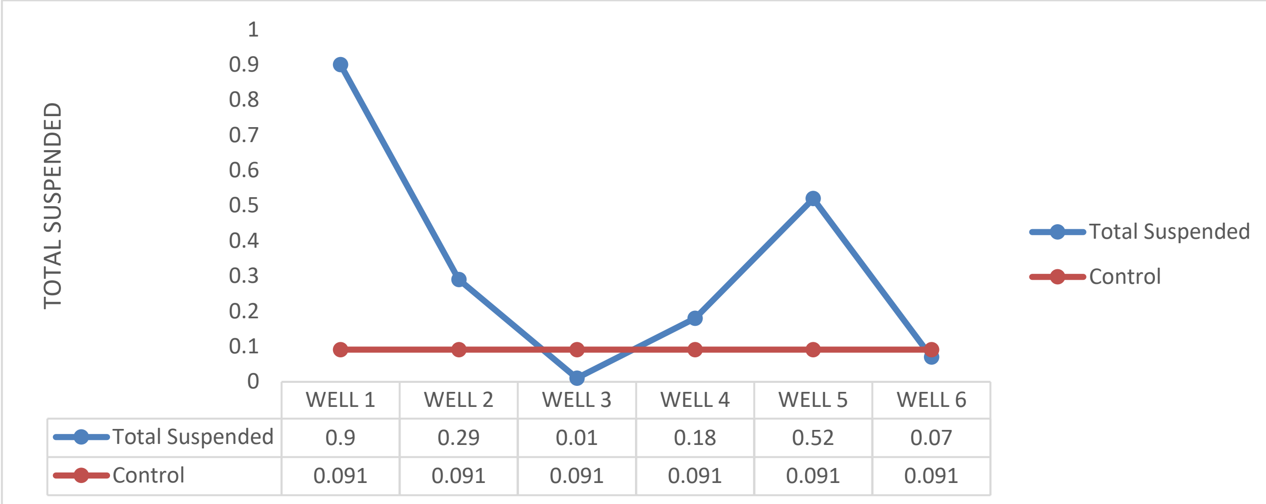

Fig 6: Line plot Total suspended vs Standards

Fig 6 is the line plot of wells when considering the borehole control as standard for the Total suspended. From the plot its obvious there is wide gap between each of the wells and the standard employed when considering total suspended as parameter of ground water.

Table 4.6: Summary table for mean, normality and one sample t-test for Total suspended of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	.32833	.333192	.136025		
		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
		Statistic	**df**	**Sig**	**Statistic**	**df**	**Sig**
	Well	.212	6	.200	.904	6	.397
One-Sample Test							
		t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	Upper
Borehole Control (0.091)	Well	1.745	5	.141	.237333	-.11233	.58700
WHO (500)	Well	-17.148	5	.000	-309.27000	-353.40041	-265.13959

Source: Researcher's extract from SPSS 25.0

Table 4.6 shows how a one-sample t test was used to examine if the total suspended samples differed from the standard control, which was designated as the borehole control of 0.237333. The sample scores were normally distributed, according to Shapiro Wilk's Test (P>0.05), and there were no outliers in the data.

The total suspended mean of the samples is (0.32833 0.033192), which is greater than the standard mean (Borehole control), but it is not statistically significant by 0.237333 (95 percent CI, -0.11233 to 0.58700), t(6) = 1.745, p =0.141.

4.2 Analysis of the Chemical Parameters of Groundwater

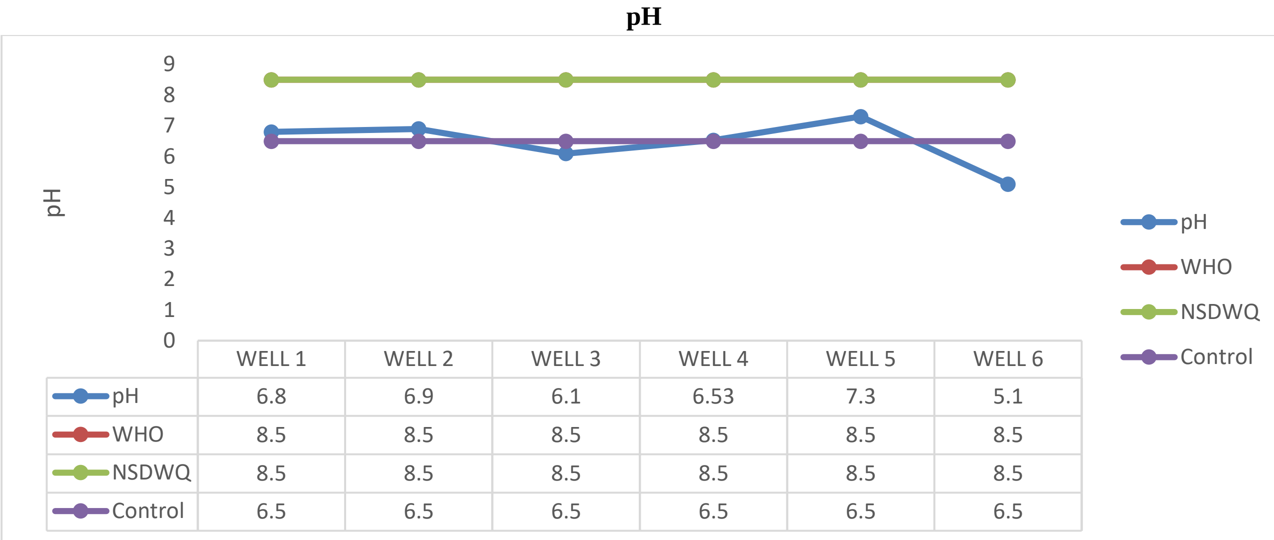

Fig 8: Line plot of pH vs Standards

Fig 8 is the line plot of samples when considering the Sample control and the WHO Standard for the pH. From the plot it suggest that a better comaparison would be between the wells and borehole control (as the standard) however there is no wide gap between the WHO standard and the samples when considering pH as the parameter for groundwater.

Table 4.8: Summary table for mean, normality and one sample t-test for pH of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	6.45500	.774435	.316162		
		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
		Statistic	**df**	**Sig**	**Statistic**	**df**	**Sig**
	Well	.205	6	.200*	.922	6	.521
One-Sample Test							
		t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	Upper
Borehole Control (6.5)	Well	-.142	5	.892	-.045000	-.85772	.76772
WHO (500)	Well	-6.468	5	.001	-2.045000	-2.85772	-1.23228

Source: Researcher's extract from SPSS 25.0

Table 4.8 is the summary table for mean, normality and one sample t-test for pH of groundwater; A one sample t-test was used to see if the different samples for pH differed from the standard control which was defined as the borehole control of -0.045000. According to Shapiro Wilk's Test ($P>0.05$), the sample scores were normally distributed, and there were no outliers in the data.

The mean of the samples for pH is (**6.45500** ± 0.774435), which is lower than the standard mean (Borehole control), is not statistically significant by -0.045000 (95% CI, -0.85772 to 0.76772) $t(5) = -0.142$, $p = 0.892$. Alternatively when considering the WHO standard it is found to be statistically significant by -2.045000 (95% CI, -2.85772 to -1.23228), $t(5) = -6.468$, $p=0.001$. From the results above, the pH concentration in the water is low; indicating that concentration of hydrogen ion in the water is not adequate. As a result, the water is acidic and its consumption would lead to various health problems.

TOTAL ACIDITY

Fig 9: Line plot of Total Acidity vs Standards

Fig 9 is the line plot of samples when considering the Sample control as the standadr for the Total Acidity. From the plot it suggest that there is a wide difference between the wells and borehole control (as the standard) when considering Total Acidity as parameter of groundwaterwater except for well1, well 4 and well 6.

Table 4.19: Summary table for mean, normality and one sample t-test for Total Acidity of groundwater

		N	**Mean**	**Std. Deviation**	**Std. Error Mean**		
	Well	6	26.16667	11.754432	4.798727		
		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
		Statistic	**df**	**Sig**	**Statistic**	**df**	**Sig**
	Well	.229	6	.200*	.900	6	.375
One-Sample Test							
		t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	Upper
Borehole Control (20)	Well	1.285	5	.255	6.166667	-6.16885	18.50219
WHO (====)	Well	====	====	====	====	====	====

Source: Researcher's extract from SPSS 25.0

In table 4.19; A one sample t test was used to see if the different samples for total alkalinity differed from the standard control which was defined as the borehole control by 0.81667. According to Shapiro Wilk's Test (P>0.05), the sample scores were normally distributed, and there were no outliers in the data.

The mean of the samples for total alkalinity is (**12.31667** ± 6.090129), which is higher than the standard mean (Borehole control), is not statistically significant by 0.81667 (95% CI, -5.57453 to 7.20786), t(5) = 0.328, p =0.756. From our results, it can be inferred that the water is acidic and thus, not palatable. Also, acidity of water is said to affect its corrosiveness and the speciation of some of its other constituents.

TOTAL ALKALINITY

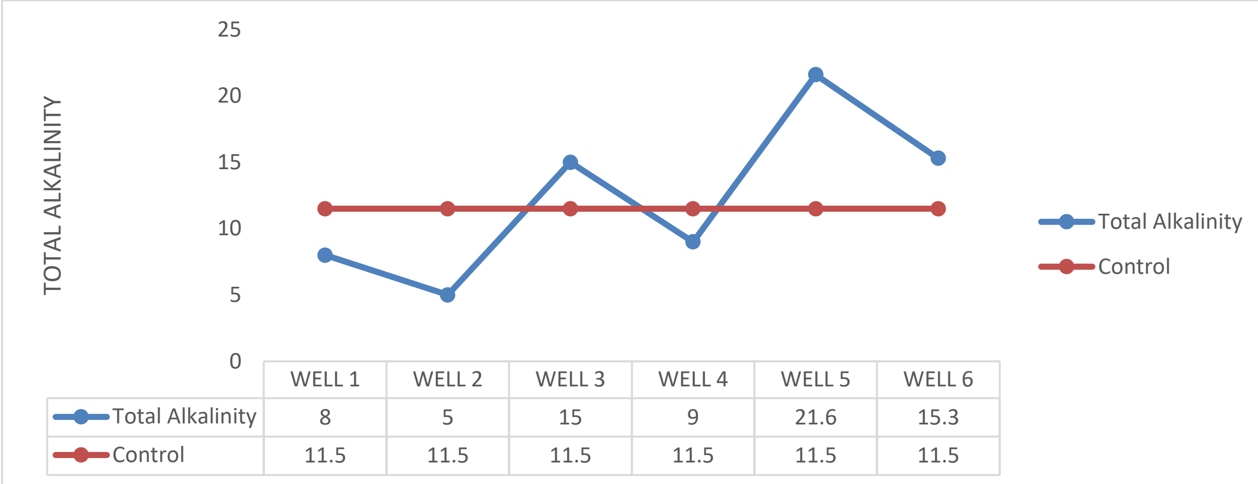

Fig 10: Line plot of Total Alkaliniity vs Standards

Fig 10 is the line plot of samples when considering the Sample control as the standadr for the Total Alkalinity. From the plot it suggets that the wells and borhole control (as the standard) when considering Total alkalinity as parameter of groundwater is not similar.

Table 4.10: Summary table for mean, normality and one sample t-test for Total Alkalinity of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	12.31667	6.090129	2.486285		
		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
		Statistic	**df**	**Sig**	**Statistic**	**df**	**Sig**
	Well	.207	6	.200*	.947	6	.716
One-Sample Test							
		t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	Upper
Borehole Control (11.5)	Well	.328	5	.756	.816667	-5.57453	7.20786
WHO (====)	Well	====	====	====	====	====	====

Source: Researcher's extract from SPSS 25.0

In table 4.10; A one sample t test was used to see if the different samples for total alkalinity differed from the standard control which was defined as the borehole control by 0.81667. According to Shapiro Wilk's Test ($P>0.05$), the sample scores were normally distributed, and there were no outliers in the data.

The mean of the samples for total alkalinity is (**12.31667** ± 6.090129), which is higher than the standard mean (Borehole control), is not statistically significant by 0.81667 (95% CI, -5.57453 to 7.20786), $t(5) = 0.328$, $p = 0.756$. Based on our results above, the alkaline contents in the water are high; hence, it is affirmed that the water has bicarbonates and hydroxides. As a result, there is consequential effect of eutrophication in the water. More so, high alkalinity, while not detrimental to humans may cause drinking water to have a flat, unpleasant taste (Adams, 2001).

Chloride

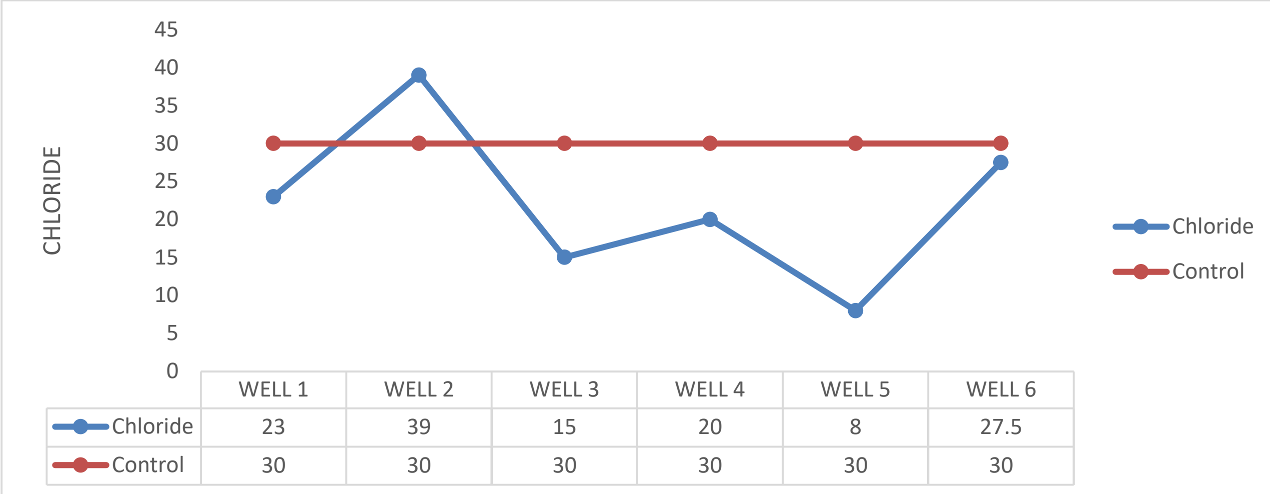

Fig 11: Line plot of Chloride vs Standards

Fig 11 is the line plot of samples when considering the Sample control as the standadr for the Chloride. From the plot it suggets that the samples and samples control (as the standard) when considering chloride as parameter of ground water is not the same except for well 6 which is approximatley the same with the borehole control.

Table 4.11: Summary table for mean, normality and one sample t-test for Chloride of groundwater

		N	**Mean**	**Std. Deviation**	**Std. Error Mean**		
	Well	6	22.08333	10.669661	4.355871		
		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
		Statistic	**df**	**Sig**	**Statistic**	**df**	**Sig**
	Well	.139	6	$.200^{*}$	.987	6	.981
One-Sample Test							
		t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	Upper
Borehole Control (30)	Well	-1.817	5	.129	-7.916667	-19.11379	3.28046
WHO (====)	Well	====	====	====	====	====	====

Source: Researcher's extract from SPSS 25.0

In table 4.11; A one sample t test was used to see if the different wells for chloride differed from the standard control defined as borehole control by -7.916667. According to Shapiro Wilk's Test (P>0.05), the sample scores were normally distributed, and there were no outliers in the data.

The mean of the samples for chloride is (**22.08333** ± 4.355871), which is lower than the standard mean (Borehole control), is not statistically significant by -7.916667 (95% CI, -19.11379 to 3.28046), t(5) = -1.817, p =0.129. The chlorine contents in the water is said to be within permissible limit. This shows that people who are drinking this water are not exposed to higher danger of hypertension.

HARDNESS

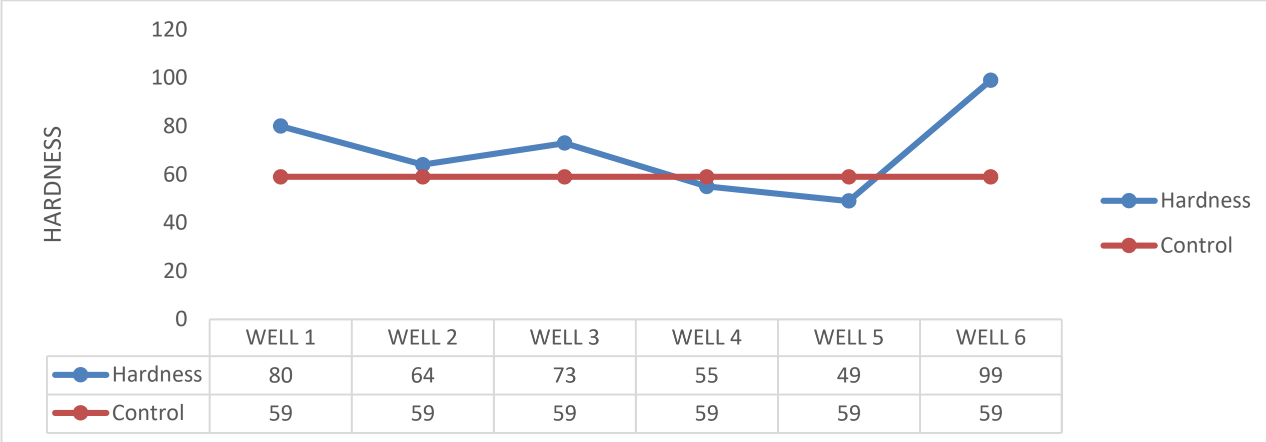

Fig 12: Line plot of Harness vs Standards

Fig 12 is the line plot of wells when considering the borehole control as the standadr for the hardness. From the plot it suggets that the well and borehole control (as the standard) when considering hardness as parameter of ground water is approximatley the same except for well 6.

Table 4.12: Summary table for mean, normality and one sample t-test for Hardness of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	70.00000	18.176908	7.420692		
		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
		Statistic	**df**	**Sig**	**Statistic**	**df**	**Sig**
	Well	.129	6	.200*	.967	6	.869
One-Sample Test							
		t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	Upper
Borehole Control (59)	Well	1.482	5	.198	11.000000	-8.07550	30.07550
WHO (====)	Well	====	====	====	====	====	====

Source: Researcher's extract from SPSS 25.0

In table 4.12; A one sample t test was used to see if the different wells for Hardness differed from the standard control defined as borehole control by 11.0000. According to Shapiro Wilk's Test ($P>0.05$), the sample scores were normally distributed, and there were no outliers in the data.

The mean of the samples for hardness is (**70.000** ± 18.176908), which is higher than the standard mean (Borehole control), is not statistically significant by 11.0000 (95% CI, -8.07550 to 30.07550), $t(5) = 1.482$, $p = 0.198$.

Generally, water hardness relates to the amount of calcium and magnesium compounds present in water. Based on our results, the water is classified as hard water. That is to say, it has high concentration of calcium and magnesium ions. So, if people within the vicinity has no other alternative to drinking water, they are advised to always boil the water or add lime to it before they can drink it or use it for domestic purposes.

PHOSPHATE

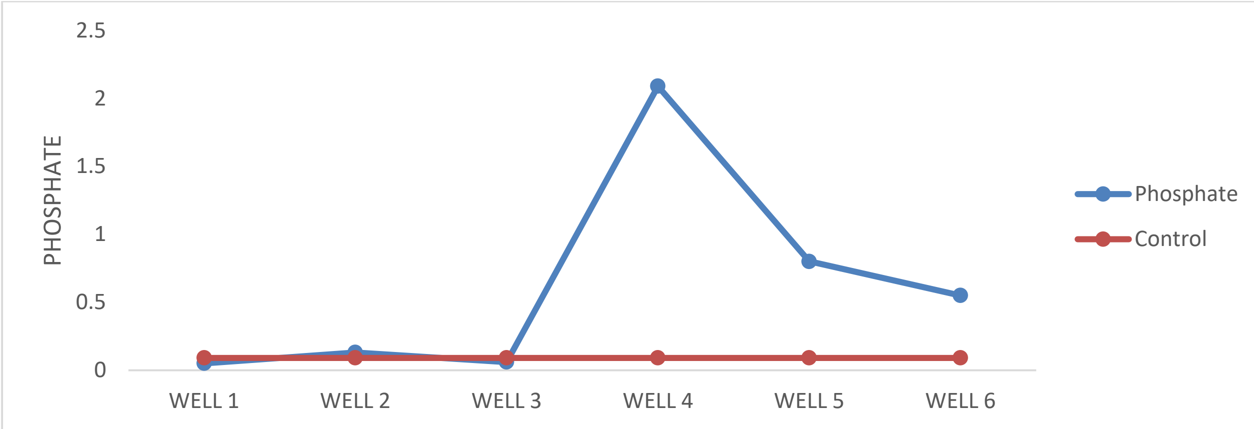

Fig 13: Line plot of Phospate vs Standard

Fig 13 is the line plot of wells when considering the borehole control as the standard for the phosphate. From the plot it suggets that the wells and borehole control (as the standard) when considering Phosphate as parameter of gorund water is approximatley the same for well 1, well 2 and well 3 only.

Table 4.13: Summary table for mean, normality and one sample t-test for phosphate of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	.61333	.784415	.320236		
		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
		Statistic	**df**	**Sig**	**Statistic**	**df**	**Sig**
	Well	.239	6	.200*	.787	6	.055
One-Sample Test							
		t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	Upper
Borehole Control (0.09)	Well	1.634	5	.163	.523333	-.29986	1.34653
WHO (====)	Well	====	====	====	====	====	====

Source: Researcher's extract from SPSS 25.0

In table 4.13; A one sample t test was used to see if the different wells for phosphate differed from the standard control defined as borehole control by 0.52333. According to Shapiro Wilk's Test (P>0.05), the sample scores were normally distributed, and there were no outliers in the data. The mean of the samples for phosphate is (**0.61333** ± 0.784415), which is higher than the standard mean (Borehole control), is not statistically significant by 0.52333 (95% CI, -0.29986 to 1.34653), t(5) = 1.634, p =0.163. Since phosphorus has gained access in the water bodies, it means that algae grow in the water, as well as other plants leading to blooms, littoral slimes, diurnal dissolved oxygen variation of great magnitude and other related problems. More so, high phosphate levels in drinking water is said to cause digestive problems in humans and animals; hence, the water is not safe for drinking or domestic use.

SULPHATE

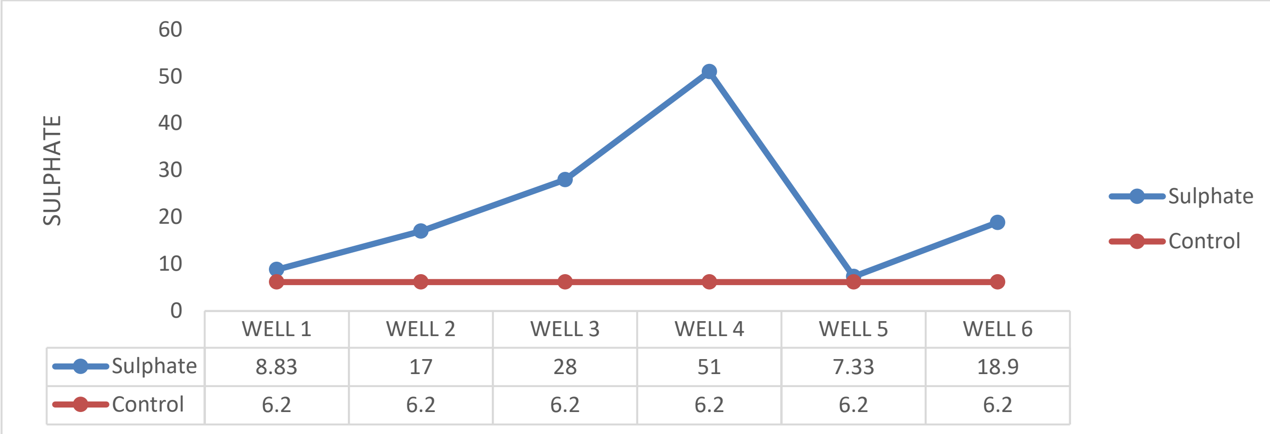

Fig 14: Line plot of Sulphate vs Standard

Fig 14 is the line plot of samples when considering the Sample control as the standadr for the sulpahte. From the plot it suggets that the wells and borehole control (as the standard) when considering sulphate as parameter of ground water is approximatley the same for well 1 and well 5.

Table 4.14: Summary table for mean, normality and one sample t-test for sulphate of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	21.84333	16.125263	6.583111		
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig	Statistic	df	Sig
	Well	.239	6	.200*	.870	6	.225
One-Sample Test							
		t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Borehole Control (6.2)	Well	2.376	5	.063	15.643333	-1.27909	32.56576
WHO (====)	Well	====	====	====	====	====	====

Source: Researcher's extract from SPSS 25.0

In table 4.14; A one sample t test was used to see if the different wells for sulphate differed from the standard control defined as borehole control by 15.64333. According to Shapiro Wilk's Test (P>0.05), the sample scores were normally distributed, and there were no outliers in the data. The mean of the samples for sulphate is (**21.8433** ± 16.125263), which is higher than the standard mean (Borehole control), is not statistically significant by 15.64333 (95% CI, -1.27909 to 32.56576), t(5) = 2.376, p =0.063. By implication, there are high contents of sulphates in the water, which indicates that it hardness cannot completely be removed by boiling or liming. In other words, the water is permanently hard.

DISSOLVED OXYGEN

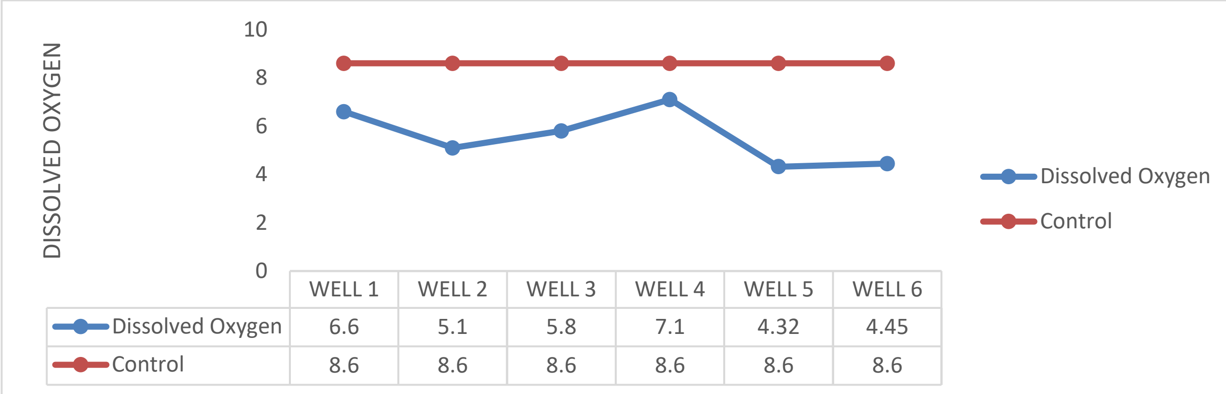

Fig 15: Line plot of Dissolved oxygen vs Standard

Fig 15 is the line plot of wells when considering the borehole control as the standard for the dissolved oxygen. From the plot it suggets that the samples and borehole control (as the standard) when considering dissolved oxygen as parameter of ground water is not the same for the wells.

Table 4.15: Summary table for mean, normality and one sample t-test for Dissolved oxygen of groundwater

		N	**Mean**	**Std. Deviation**	**Std. Error Mean**		
	Well	6	5.56167	1.139481	.465191		
		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
		Statistic	**df**	**Sig**	**Statistic**	**df**	**Sig**
	Well	.169	6	.200*	.927	6	.555
One-Sample Test							
		t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	Upper
Borehole Control (8.6)	Well	-6.531	5	.001	-3.038333	-4.23415	-1.84252
WHO (====)	Well	====	====	====	====	====	====

Source: Researcher's extract from SPSS 25.0

In table 4.15; a one sample t-test was used to see if the concentration of dissolved oxygen in the wells differs from the standard control. From our estimate, the mean differenceobtained was −3.038333. According to Shapiro Wilk's Test (P>0.05), the sample scores were normally distributed, and there were no outliers in the data. The mean of the samples for dissolved oxygen is (**5.56167** ± 1.139481), which is lower than the standard mean (Borehole control), is statistically significant by -3.038333 (95% CI, -4.23415 to -1.84252), t(5) = -6.531, p =0.001.

The dissolved oxygen depicts the quantity of oxygen in the water. The decrease in volume of dissolved oxygen in the water indicates that the water is polluted. However, survival of aquatic life is in danger (Narayanan, 2009; Lenntech, 2012).

NITRATE

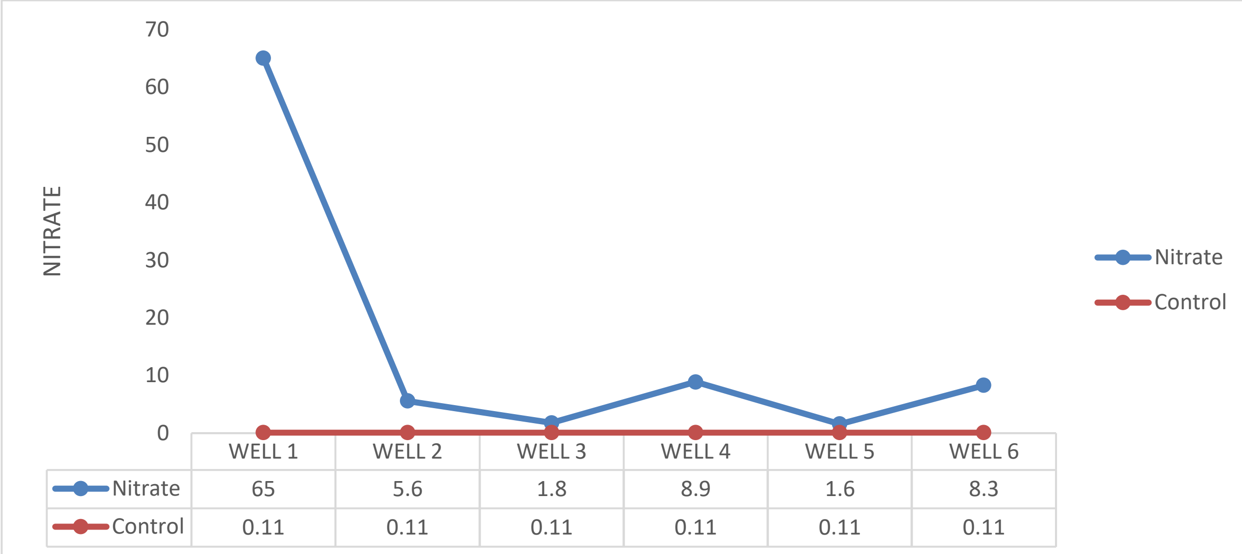

Fig 16: Line plot of Nitrate vs Standard

Fig 16 is the line plot of wells when considering the borehole control as the standadr for the Nitrate. From the plot it suggets that the well and the standards such as borehole control, (as the standard) when considering nitrate as parameter of ground water is approximatley similar except for well 1.

Table 4.16: Summary table for mean, normality and one sample t-test for Nitrate of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	15.20000	24.592763	10.039954		
		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
		Statistic	**df**	**Sig**	**Statistic**	**df**	**Sig**
	Well	.434	6	.001	.611	6	.111
One-Sample Test							
		t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	Upper
Borehole Control (0.11)	Well	1.503	5	.193	15.090000	-10.71852	40.89852
WHO (====)	Well	====	====	====	====	====	====

Source: Researcher's extract from SPSS 25.0

In table 4.16; A one sample t test was used to see if the different wells for nitrate differed from the standard control defined as borehole control by 15.09. According to Shapiro Wilk's Test (P>0.05), the sample scores were normally distributed, and there were no outliers in the data. the average value of the nitrate for the well is (**5.56167** ± 1.139481), which is higher than the standard mean (Borehole control). The variation is not statistically significant by 15.09 (95% CI, -10.71852 to 40.89852) t(5) = 1.503, p =0.193. Based on our results as presented above, there is high concentration of nitrates in the water; hence, the hardness in the water cannot be removed by boiling or adding lime (liming). Also, excessive concentration of nitrate in the water shows that its consumption can cause methemoglobinemia-the blue baby disease (cyanosis) in infants (less than six months) and stomach disorder in adults (Johnson et al., 1987; Kumar et al., 2006; Longe & Balogun, 2010).

MAGNESIUM HARDNESS

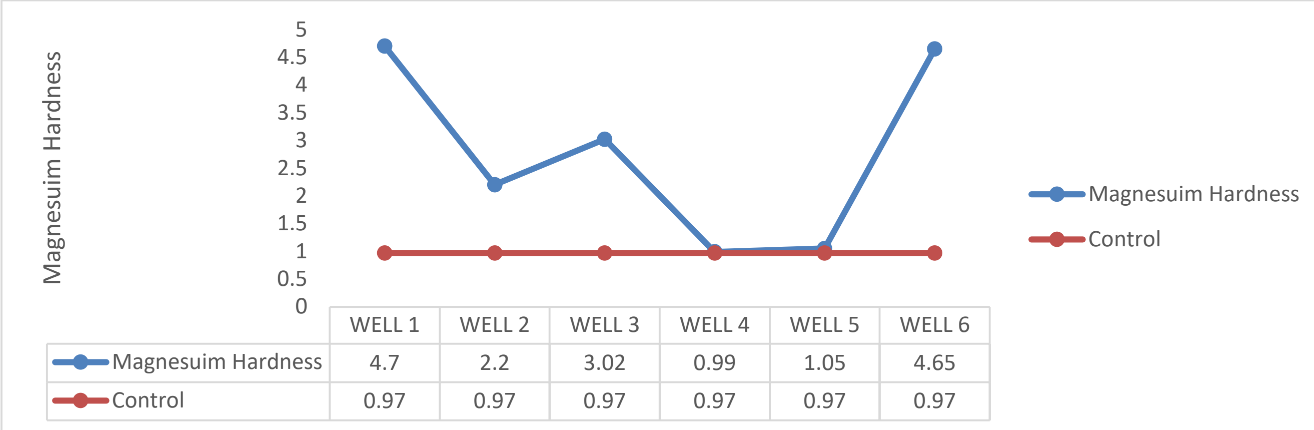

Fig 17: Line plot of Magnesuim Hardness vs Standard

Fig 17 is the line plot of well when considering the Sample control as the standadr for the magnesuim hardness. From the plot it suggets that the well and borehole control (as the standard) when considering magnesuim hardness as parameter of ground water is not the same except for well 4 and 5 that are approximately the similar.

Table 4.17: Summary table for mean, normality and one sample t-test for Magnesium Hardness of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	1.659728	.677581	2.76833		
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig	Statistic	df	Sig
	Well	.205	6	.200*	.873	6	.240
One-Sample Test							
		t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Borehole Control (0.97)	Well	2.654	5	.045	1.798333	.05656	3.54011
WHO (====)	Well	====	====	====	====	====	====

Source: Researcher's extract from SPSS 25.0

In table 4.17; A one sample t test was used to see if the different wells for magnesium hardness differed from the standard control defined as borehole control by 1.79833. According to Shapiro Wilk's Test (P>0.05), the sample scores were normally distributed, and there were no outliers in the data. The mean of the sample for magnesium hardness is (**5.56167** ± 1.139481), which is higher than the standard mean (Borehole control), is statistically significant by 1.79833 (95% CI, 0.05656 to 3.54011), t(5) = 2.654, p =0.045.

CALCIUM HARDNESS

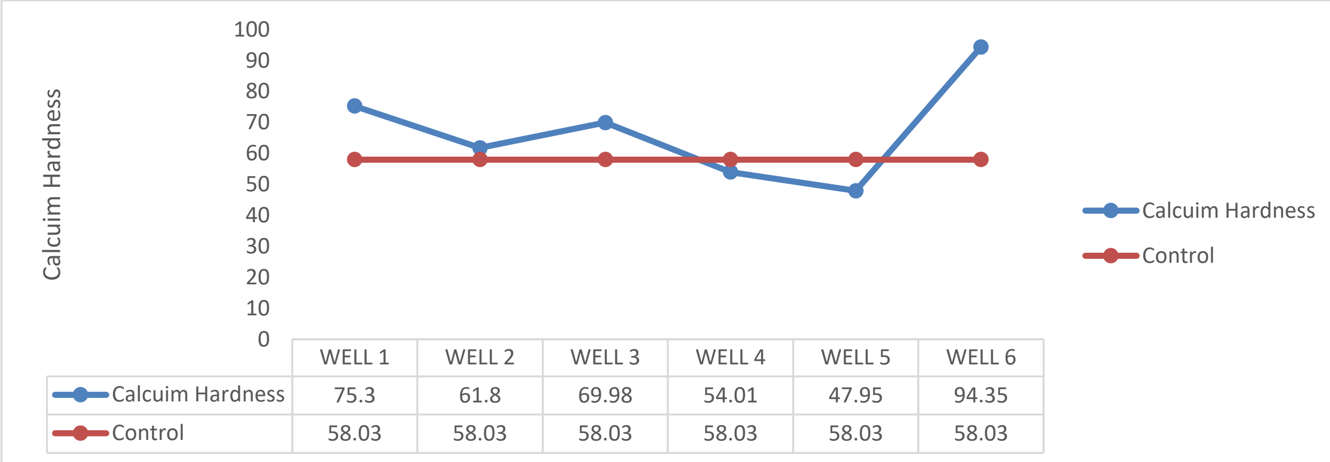

Fig 18: Line plot of Calcium Harness vs Standards

Fig 18 is the line plot of wells when considering the borehole control as the standard for the calcuim hardness. From the plot it suggets that the wells and borehole control (as the standard) when considering calcuim hardness as parameter of ground water looks similar for well 2 and well 4.

Table 4.18: Summary table for mean, normality and one sample t-test for Calcium hardness of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	16.638230	6.792529	67.23167		
		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
		Statistic	**df**	**Sig**	**Statistic**	**df**	**Sig**
	Well	.147	6	.200*	.964	6	.851
One-Sample Test							
		t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	Upper
Borehole Control (58.3)	Well	1.355	5	.234	9.201667	-8.25908	26.66242
WHO (====)	Well	====	====	====	====	====	====

Source: Researcher's extract from SPSS 25.0

In table 4.18; A one sample t test was used to see if the different wells for calcium hardness differed from the standard control defined as borehole control by 9.201667. According to Shapiro Wilk's Test (P>0.05), the sample scores were normally distributed, and there were no outliers in the data. The mean of the sample for calcium hardness is (**67.23167** ± 16.638230), which is higher than the standard mean (Borehole control), is not statistically significant by 9.201667 (95% CI, -8.25908 to 26.66242); $t(5) = 1.355$, $p = 0.234$.

4.3 Analysis for Heavy Metals of Groundwater

Fig 19: Line plot of Zinc vs Standards

Fig 19 is the line plot of wells when considering the borehole control and the WHO Standard for the zinc. From the plot it suggest that there is no better comaparison between the wells and borehole control (as the standard) except for well 1, well 4and well 6 which has a mild similarities between the borehole contron considering zinc as a parameter of goundawater. Also there is wide gap between the WHO standard and the wells when considering zinc as the parameter of ground water.

Table 4.19: Summary table for mean, normality and one sample t-test for Zinc of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	.632808	.258343	.56133		
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig	Statistic	df	Sig
	Well	.236	6	.200*	.873	6	.238
One-Sample Test							
		t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Borehole Control (0.031)	Well	2.053	5	.095	.530333	-.13376	1.19442
WHO (50)	Well	-191.369	5	.000	-49.438667	-50.10276	-48.77458

Source: Researcher's extract from SPSS 25.0

In table 4.19; A one sample t test was used to see if the different samples for zinc differed from the standard control which was defined as the borehole control of 0.530333. According to Shapiro Wilk's Test ($p>0.05$), the sample scores were normally distributed, and there were no outliers in the data.

The mean of the samples for zinc is (**0.56133** ± 0.6328), which is higher than the standard mean (Borehole Control), is not statistically significant by 0.530333 (95% CI, -0.13376 to 1.19442) $t(5) = 2.053$, $p = 0.095$. With high concentration of Zinc, the water is said to be corrosive.

LEAD

Fig 20: Line plot of Lead vs Standards

Fig 20 is the line plot of samples when considering the borehole control and the WHO Standard for the lead. From the plot it suggest that is a better comaparison between the wells and WHO standard for only well 2 and well 5 for the lead parameter of groundwater.

Table 4.20: Summary table for mean, normality and one sample t-test for Lead of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	.004401	.001797	.01217		
		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
		Statistic	**df**	**Sig**	**Statistic**	**df**	**Sig**
	Well	.189	6	.200*	.965	6	.854
One-Sample Test							
		t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	Upper
Borehole Control (0.001)	Well	6.215	5	.002	.011167	.00655	.01578
WHO (0.01)	Well	1.206	5	.282	.002167	-.00245	.00678

Source: Researcher's extract from SPSS 25.0

A one sample t test was employed in table 4.20 to examine if the different lead samples differed from the standard control, which was specified as the borehole control of 0.011167. The sample scores were normally distributed, according to Shapiro Wilk's Test ($P>0.05$), and there were no outliers in the data.

The sample mean for lead is (0.01217 0.004401), which is higher than the standard mean (Borehole Control), and is statistically significant by 0.011167 (95 percent CI, 0.00655 to 0.01578) $t(5) = 6.215$, $p = 0.002$. From our results, Lead was observed to be above permissible limits. Lead has many toxic effects on human health with children being the most vulnerable population (Payne, 2008). Based on comparison with control sample, the concentrations of Lead in the water is enough to cause serious health challenges to the people. Lead has been implicated in various diseases such as anemia, brain damage, anorexia, mental deficiency, vomiting and even death in humans (Bulut & Baysal, 2006; Ogundiran & Afolabi, 2008). Lead consumption is generally carcinogenic.

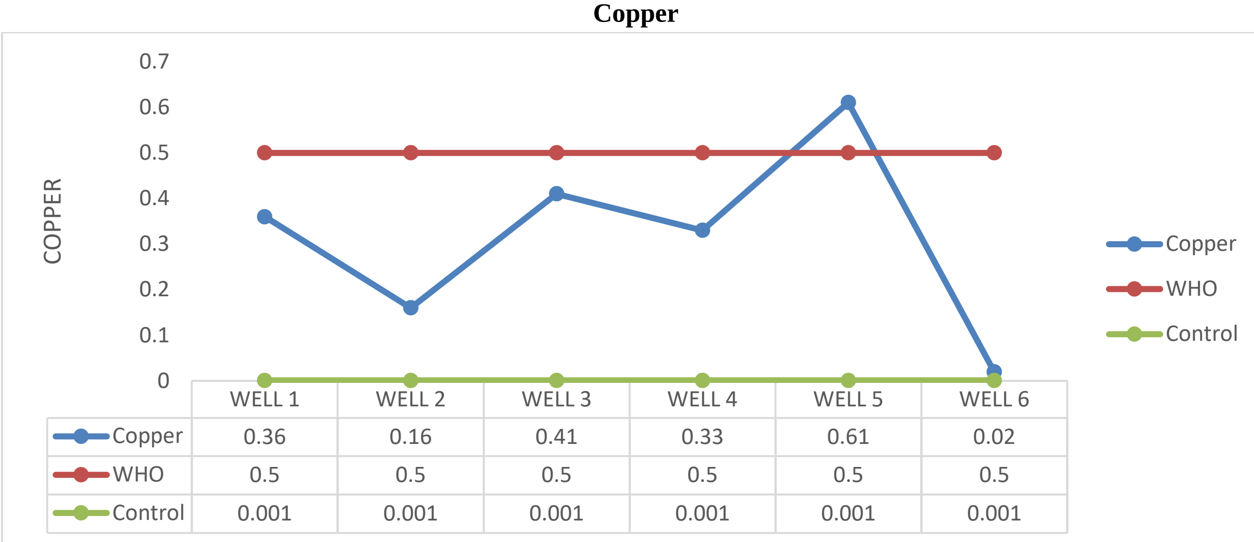

Fig 21: Line plot of copper vs Standards

Fig 21 is the line plot of wells when considering the borehole control and the WHO Standard for the copper. From the plot it suggest that no better comaparison would be between the wells and borehole control (as the standard), except for well 6 which is approximatly similar to the borehole control. There is wide gap between the WHO standard and the wells when considering copper as the parameter of groundwater.

Table 4.21: Summary table for mean, normality and one sample t-test for Copper of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	.31500	.204622	.083536		
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig	Statistic	df	Sig
	Well	.196	6	.200*	.977	6	.934
One-Sample Test							
		t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Borehole Control (0.001)	Well	3.759	5	.013	.314000	.09926	.52874
WHO (0.05)	Well	-2.215	5	.078	-.185000	-.39974	.02974

Source: Researcher's extract from SPSS 25.0

Table 4.21 is the summary table for mean, normality test and one sample t-test for copper of groundwater; A one sample t test was used to see if the different samples for copper differed from the standard control which was defined as the borehole control of 0.31400. According to Shapiro Wilk's Test (P>0.05), the sample scores were normally distributed, and there were no outliers in the data.

The mean of the samples for copper is (**0.31500** ± 0.204622), which is higher than the standard mean (Borehole Control), is statistically significant by 0.31400 (95% CI, 0.09926 to 0.52874) t (5) = 3.759, p =0.013. The implication of the result is that the water when consumed can cause headaches, stomachaches, dizziness, vomiting, diarrhea and other gastrointestinal disorders. Also, as recognized by the Agency for Toxic Substances and Disease Registry (2004), intentionally high uptakes of copper may cause liver and kidney damage which may eventually lead to death.

ARSENIC

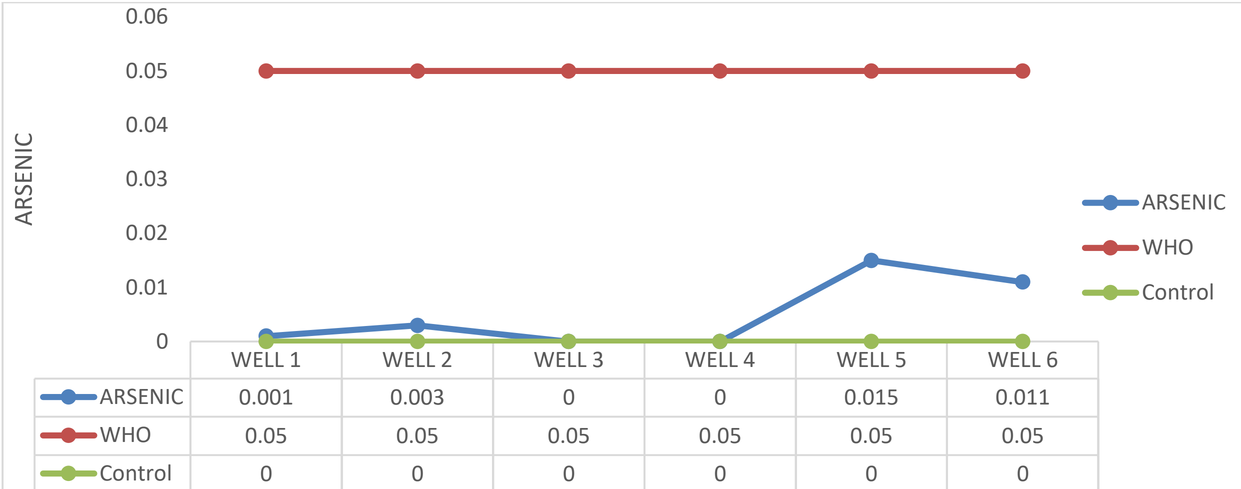

Fig 22: Line plot of Arsenic vs Standards

Fig 22 is the line plot of wells when considering the borehole control and the WHO Standard for the arsenic. From the plot it suggest that there is a better comaparison between the wells and borehole control (as the standard), except for well 5 and well 6 which is not similar to the borehole control. There is wide gap between the WHO standard and the wells when considering arsenic as the parameter of ground water.

Table 4.22: Summary table for mean, normality and one sample t-test for Arsenic of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	.00500	.006419	.002620		
		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
		Statistic	**df**	**Sig**	**Statistic**	**df**	**Sig**
	Well	.289	6	.128	.809	6	.071
One-Sample Test							
		t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	Upper
Borehole Control (0)	Well	1.908	5	.115	.005000	-.00174	.01174
WHO (0.05)	Well	-17.173	5	.000	-.045000	-.05174	-.03826

Source: Researcher's extract from SPSS 25.0

In table 4.22; A one sample t test was used to see if the different samples for arsenic differed from the standard control which was defined as the borehole control of 0.005. According to Shapiro Wilk's Test (P>0.05), the sample scores were normally distributed, and there were no outliers in the data.

The mean of the samples for arsenic is (**0.005** ± 0.0006419), which is higher than the standard mean (Borehole Control), is not statistically significant by 0.005 (95% CI, -0.00174 to 0.01174), t(5) = 1.908, p =0.115.

MANGANESE

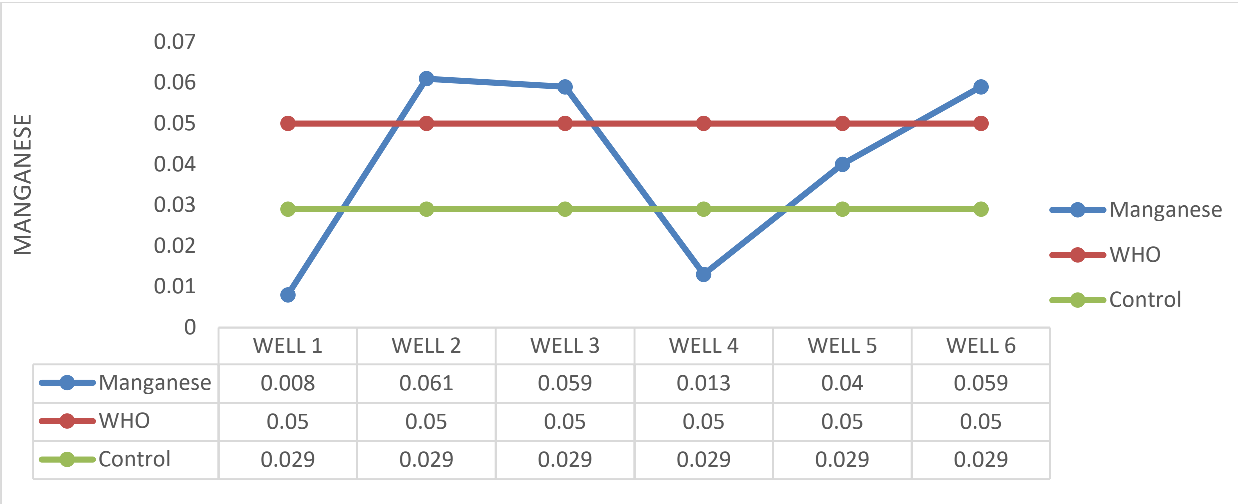

Fig 23: Line plot of Manganese vs Standards

Fig 23 is the line plot of wells when considering the borehole control and the WHO Standard for the manganese. From the plot it suggest that no better comaparison would be between the wells and borehole control (as the standard) similarly there is wide gap between the WHO standard and the samples when considering manganese as the parameter of ground water.

Table 4.23: Summary table for mean, normality and one sample t-test for Manganese of groundwater

		N	**Mean**	**Std. Deviation**	**Std. Error Mean**		
	Well	6	.04000	.024150	.009859		
		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
		Statistic	**df**	**Sig**	**Statistic**	**df**	**Sig**
	Well	.284	6	.141	.812	6	.076
One-Sample Test							
		t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	Upper
Borehole Control (0.029)	Well	1.116	5	.315	.011000	-.01434	.03634
WHO (0.05)	Well	-17.173	5	.000	-.045000	-.05174	-.03826

Source: Researcher's extract from SPSS 25.0

Table 4.23 is the summary table for mean, normality test and one sample t-test for manganese; A one sample t test was used to see if the different samples for manganese differed from the standard control which was defined as the borehole control of 0.005. According to Shapiro Wilk's Test ($P>0.05$), the sample scores were normally distributed, and there were no outliers in the data.

The mean of the samples for manganese is (**0.04** ± 0.024150), which is higher than the standard mean (Borehole Control), is not statistically significant by 0.005 (95% CI, -0.01434 to 0.03634) $t(5) = 1.116$, $p = 0.315$. With high concentration of Manganese, the water is affirmed not to be good for drinking.

Chromium

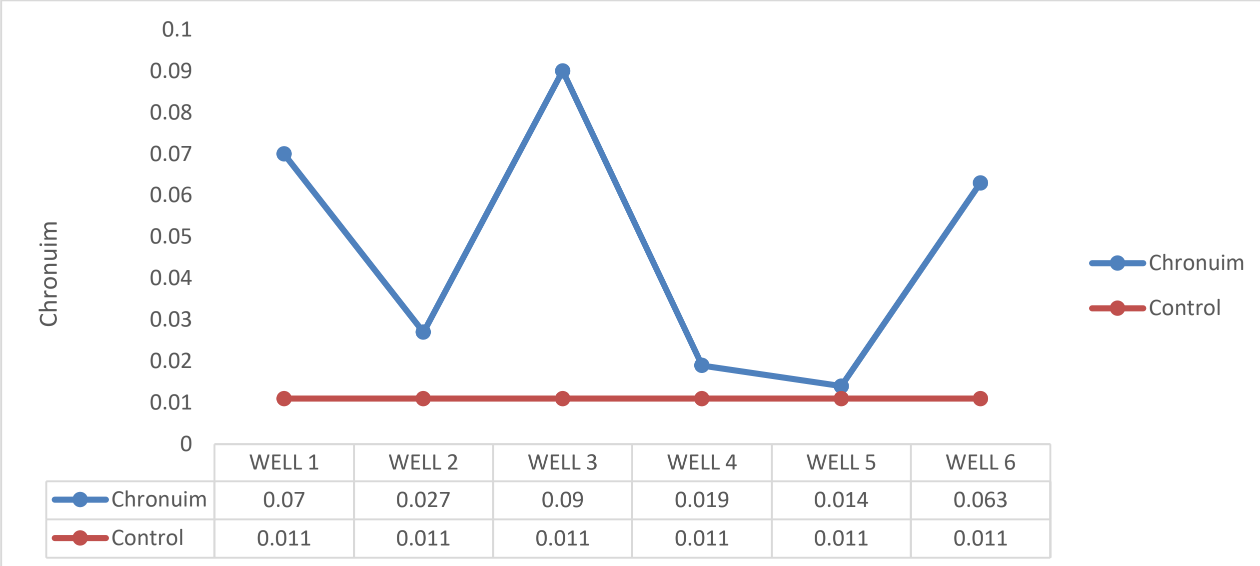

Fig 24: Line plot of Chromium vs Standards

Fig 24 is the line plot of wells when considering the borehole control and the WHO Standard for the chromium. From the plot it suggest that no better comaparison would be between the wells and borehole control (as the standard) except for well 5 that looks similar to the borehole control.

Table 4.24: Summary table for mean, normality and one sample t-test for Chromium of groundwater

		N	**Mean**	**Std. Deviation**	**Std. Error Mean**		
	Well	6	.04717	.031327	.012789		
		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
		Statistic	**df**	**Sig**	**Statistic**	**df**	**Sig**
	Well	.240	6	.200*	.897	6	.359
One-Sample Test							
		t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	Upper
Borehole Control (0.011)	Well	2.828	5	.037	.036167	.00329	.06904
WHO (0.05)	Well	=====	====	====	=====	====	====

Source: Researcher's extract from SPSS 25.0

In table 4.24; A one sample t test was used to see if the different samples for chromium differed from the standard control which was defined as the borehole control of 0.036167. According to Shapiro Wilk's Test ($P>0.05$), the sample scores were normally distributed, and there were no outliers in the data.

The mean of the samples for chromium is (**0.04717** ± 0.031327), which is higher than the standard mean (Borehole Control), is statistically significant by 0.036167 (95% CI, 0.00329 to 0.06904), $t(5) = 2.828$, $p = 0.037$.

IRON

Fig 25: Line plot of Iron vs Standards

Fig 25 is the line plot of wells when considering the borehole control and the WHO Standard for the iron. From the plot it suggest that no better comaparison would be between the wells and borehole control (as the standard), except for well 1 , well 5 and well 6 which displayed similarities with the borehole control. There is wide gap between the WHO standard and the wells when considering iron as the parameter of ground water except for well 1, well 5 and well 6.

Table 4.25: Summary table for mean, normality and one sample t-test for Iron of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	.07683	.075160	.030684		
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig	Statistic	df	Sig
	Well	.264	6	.200*	.787	6	.045
One-Sample Test							
		t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Borehole Control (0.019)	Well	1.885	5	.118	.057833	-.02104	.13671
WHO (0.03)	Well	1.526	5	.187	.046833	-.03204	.12571

Source: Researcher's extract from SPSS 25.0

A one sample t test was employed in table 4.25 to examine if the different iron samples differed from the standard control, which was specified as the borehole control of 0.057833. The sample scores were normally distributed, according to Shapiro Wilk's Test (P>0.05), and there were no outliers in the data.

The sample mean for iron is (0.07683 0.075160), which is higher than the standard mean (Borehole Control), but it is not statistically significant by 0.057833 (95 percent CI, -0.02104 to 0.13671); t(5) = 1.886, p =0.118. Also, higher than the WHO permissible limit (0.03) but not statistically significant (t(5) = 1.526, p =0.187>0.05). Based on this result, it can be inferred that the water can stain clothes when used in washing (Adams, 2001). Also, presence of Iron in water can lead to change of colour of groundwater (Rowe et al., 1995). Meanwhile, people who are drinking the water are therefore exposed to some health dangers among which are conjunctivitis, choroditis and retinitis.

MAGNESIUM

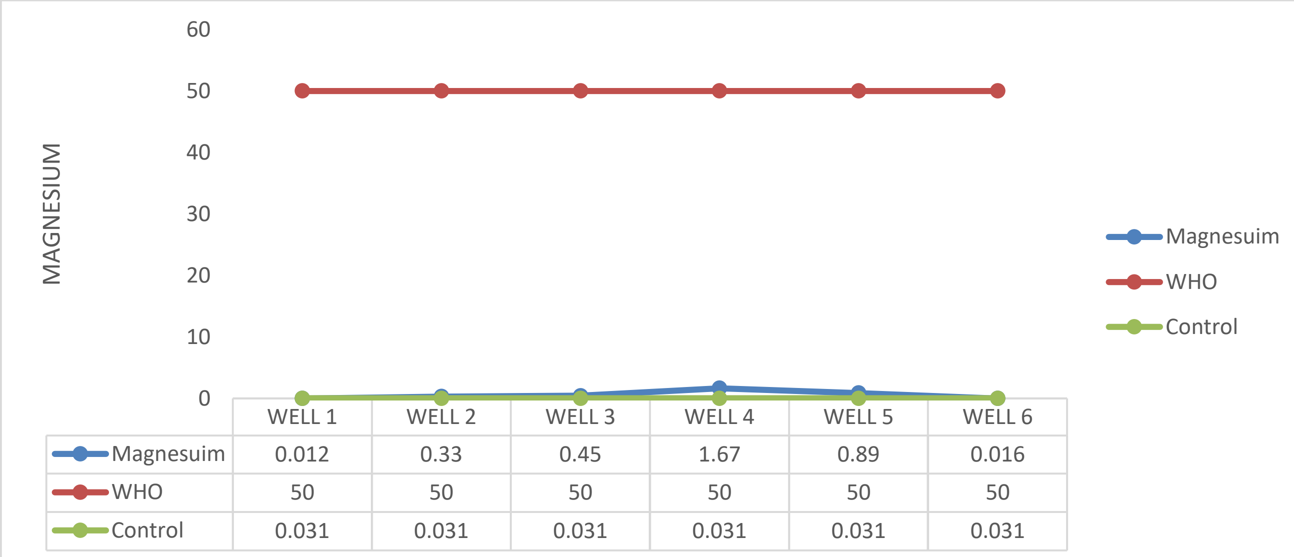

Fig 26: Line plot of magnesium vs Standards

Fig 26 is the line plot of wells when considering the borehole control and the WHO Standard for the magnesuim. From the plot it suggest that there is a better comaparison would be between the wells and borehole control (as the standard). There is also wide gap between the WHO standard and the wells when considering magnesuim as the parameter of groundwater.

Table 4.26: Summary table for mean, normality and one sample t-test for Magnesium of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	.56133	.632808	.258343		
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig	Statistic	df	Sig
	Well	.236	6	.200*	.873	6	.238
One-Sample Test							
		t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Borehole Control (0.031)	Well	2.053	5	.095	.530333	-.13376	1.19442
WHO (50)	Well	-191.369	5	.000	-49.438667	-50.10276	-48.77458

Source: Researcher's extract from SPSS 25.0

Table 4.26 shows the results of a one-sample t test to see if the Magnesium samples differed from the standard control, which was specified as the borehole control of 0.530333. The sample scores were normally distributed, according to Shapiro Wilk's Test (P>0.05), and there were no outliers in the data.

The mean magnesium concentration in the samples is (0.56133 0.0632808), which is greater than the standard mean (Borehole Control) but not statistically significant by 0.530333. (95 percent CI, -0.13376 to 1.19442) p =0.095, t(5) = 2.053.

4.4 Analysis of the Bacteriological Parameters of Groundwater

TOTAL COLIFORM

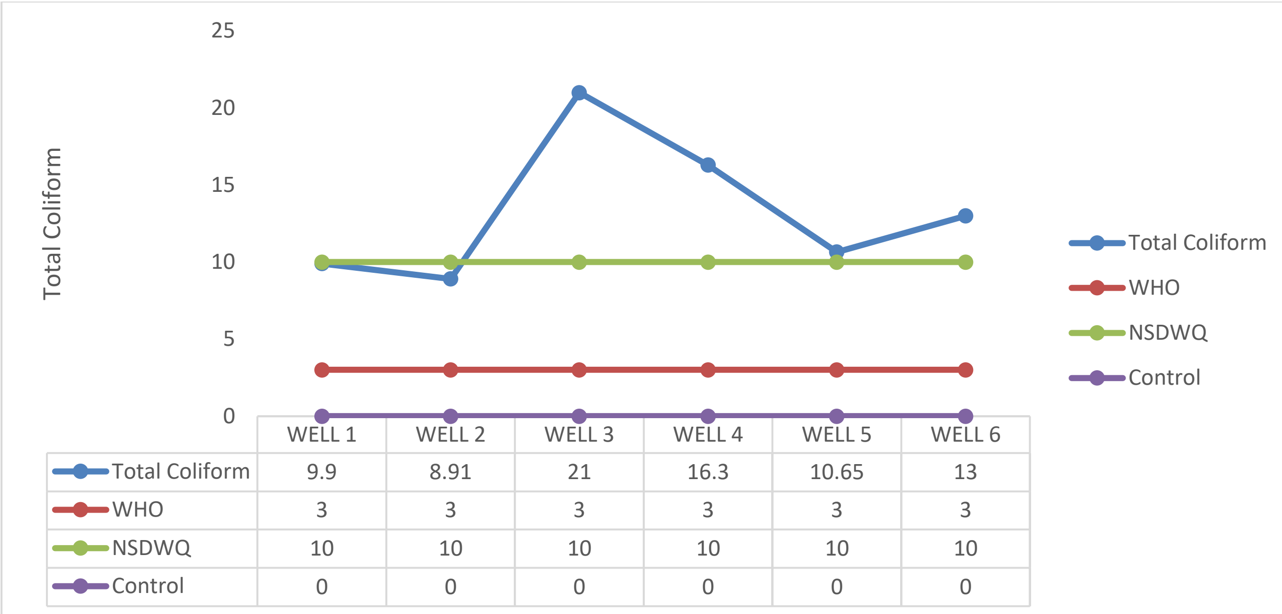

Fig 27: Line plot of total coliform vs standard

Fig 27 is the line plot of wells when considering the borehole control and the WHO Standard for the total coliform. From the plot it suggest that the comaparison between the wells and NSDWQ is quite similar for well 1, well2, well5 and well 6 when considering total coliform as the parameter of groundwater.

Table 4.27: Summary table for mean, normality and one sample t-test for total coliform of groundwater

		N	**Mean**	**Std. Deviation**	**Std. Error Mean**		
	Well	6	13.29333	4.609432	1.881793		
		Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
		Statistic	**df**	**Sig**	**Statistic**	**df**	**Sig**
	Well	.217	6	.200*	.900	6	.373
One-Sample Test							
		t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
						Lower	Upper
Borehole Control (3)	Well	5.470	5	.003	10.293333	5.45603	15.13064
WHO /NSDWQ (10)	Well	1.750	5	.141	3.293333	-1.54397	8.13064

Source: Researcher's extract from SPSS 25.0

In table 4.27; A one sample t test was used to see if the different samples for total coliform differed from the standard control which was defined as the WHO Standard of 10.29333. According to Shapiro Wilk's Test (P>0.05), the sample scores were normally distributed, and there were no outliers in the data. The mean of the samples for total coliform is (**13.29333** ± 4.609432), which is higher than the standard mean (WHO Standard), is not statistically significant by 10.29333 (95% CI, 5.45603 to 15.13064), t(5) = 5.470, p =0.003. Since the total coliform counts of the sampled wells were above the World Health Organisation's permissible limits for drinking water, the water is confirmed to be polluted.

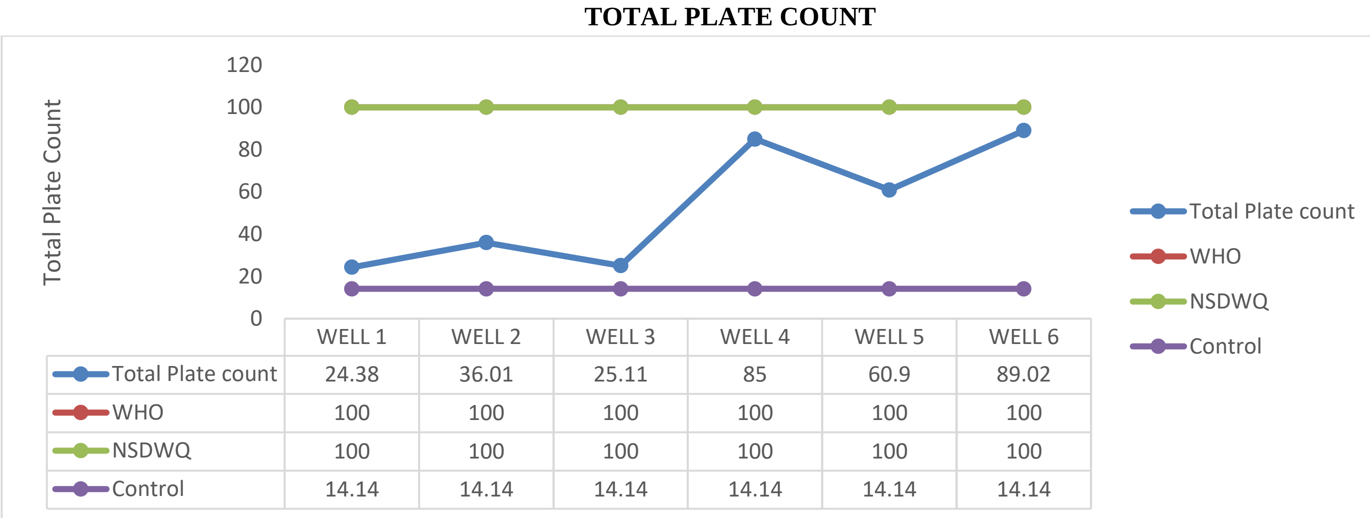

Fig 28: Line plot of total plate count vs standard

Fig 28 is the line plot of wells when considering the borehole control and the WHO Standard for the total coliform. From the plot it suggest that the comaparison between the wells and borehole control is quite similar for well 1, well2 and well 3 when considering total coliform as the parameter of groundwater. Other standards has a wide gap with the different wells for total plate count of groundwater.

Table 4.28: Summary table for mean, normality and one sample t-test for total plate count of groundwater

		N	Mean	Std. Deviation	Std. Error Mean		
	Well	6	53.40333	29.218114	11.928245		
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig	Statistic	df	Sig
	Well	.224	6	$.200^{*}$	.859	6	.187
One-Sample Test							
		t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Borehole Control (14.1)	Well	3.292	5	.022	39.263333	8.60080	69.92586
WHO /NSDWQ (10)	Well	-3.906	5	.011	-46.596667	-77.25920	-15.93414

Source: Researcher's extract from SPSS 25.0

Table 4.28 is the summary table for mean, normality and one sample t-test of total plate count of groundwater; A one sample t test was used to see if the different samples for total plate count differed from the standard control which was defined as the borehole control of 39.26333. According to Shapiro Wilk's Test (P>0.05), the sample scores were normally distributed, and there were no outliers in the data.

The mean of the samples for total plate count is (**29.218114** ± 11.928245), which is higher than the standard mean (Borehole control), is statistically significant by 39.26333 (95% CI, 8.60080 to 69.92586); t(5) = 3.292, p =0.022.

V. SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of Findings

This study involved the analysis of the impact of landfill leachate on the quality of groundwater obtained from groundwater source, stream water in Agbani metropolis and comparing them with World Health Organisation (2006) Standards for drinking water and Nigerian Standard for Drinking Water Quality (2007) with a view to determining the status of groundwater quality in the study area. There were variations in some of the physicochemical, bacteriological and heavy metal constituents found in the groundwater sources of the current study. This differential distribution was mainly associated with geology of the study area where the wells are sampled and also the presence of industrial and domestic activities being carried out within the area.

The temperature of the samples was all above the critical temperature of 25^0C as stated by WHO (2006) Standard for drinking Water and NSDWQ (2007). Only one sample (well 3) had a temperature reading of 25ºC. Turbidity of the water is within acceptable level (i.e., within WHO recommended standard). Although, the water is not good for consumption by the people within the vicinity since the turbidity level of the water is above control (0.009NTU). The water is odourless and has no taste. The Electrical Conductivity (EC) varied in the wells. The EC in all the sampled wells were lower than WHO (2006) permissible limit and NSDWQ (2007) recommended standard. This indicates low presence of dissolved and suspended solids in the water samples. Also, this was supported by the low values of sulphates, nitrates, and chlorides and the metals, Zinc, Magnesium, Copper and Arsenic. The pH values however, were in the zone of acidity that was below 7.0 indicating slight acidity in the groundwater in the study area and were within the WHO (2006) permissible limit for drinking water and NSDWQ (2007). The groundwater is colourless.But the clear nature of the water does not suggest its purity as we have seen in the total dissolve solids. Nitrites were low and suggest their paucity in the rocks or that the chemical processes beneath do not permit their release in large qualities. Also, the character of chloride distribution in the groundwater suggests the varying rate of ingrain of chloride laden blackish water inwards.

Consequently, the bacteriological properties such as coliform count as a result of human activities within the study area varied in the wells

The geologic history of the Agbani suggests some uniformity in character of the strata which appears to have made the physico-chemical characteristics of the groundwater samples in the study area to almost have a uniform nature. However, direct comparison of the results obtained from the laboratory analyses of the water samples, compared with WHO (2006) standards and NSDWQ (2007) indicates permissible limits of the variables for drinking water quality; a confirmation that the groundwater in Agbani is not too bad for human consumption as regards to physico-chemical parameters.

However, the major source of worry or failure in the quality of ground water in the area is with the coliform count. Also, the relatively high coliform counts implied that majority of the wells were polluted. The coliform counts obtained from the sampled wellsare above the WHO (2006) recommended standard for drinking water and NSDWQ (2007)). Therefore, the groundwater in the study area should be treated for coliform count before consumption.

5.2 Conclusion

Water is a basic requirement of healthy life and healthy living. The situation is made clearer against the burgeoning population of Nigerian (NPC, 2007). The problem of securing healthy water for the people continues to receive the attention of government, academics, health services, institutions, non-governmental organizations (NGOS) and community-based organizations (CBOS). The World Health Organization has made a clear statement that the world is facing imminent water crisis, therefore the assessment of water quality consumed by man is very important. As a result, this research work has taken steps to describe and characterize the sources of groundwater pollution in Agbani. There are so many criteria to be taken into considerations before digging a well. However, due to lack of awareness and understanding, some of these important features are usually neglected in Agbani. In this study, water from various wells in the area is not safe for human consumption due to pollution by microbial parameters. The Inhabitants of the area are unaware of the presence and impact of consumption of chemically and faecally polluted water due to lack of knowledge and its aesthetically attractive nature. Although the wells are safer to an extent, they all contain some element of pollutants mostly coliform count. The pollutants are detrimental to health; therefore, inhabitants of the community should treat their well water by boiling, filtering or chemical sterilization before consumption.

5.3 Recommendations

Based on the findings above, the following recommendations were made:

i) There is every need for constant monitoring of the groundwater quality to ensure that water quality parameters do not build up to levels that will be of environmental concern. Any groundwater extraction in the study area should be treated for feacal microbial pollutants.
ii) There is also need for aggressive public awareness by way of organizing seminars such that the residents are aware and educated on the proper way of constructing shallow wells, and also exposed to boiling of water before drinking and improving sanitation in the environment. In other words, providing them with requisite knowledge that aesthetically attractive and colourless water can be unsafe for human consumption, and that all water sources need to be further tested before consumption.
iii) Routine check of the quality of domestic water supply in the study area should be a regular exercise needed, so as to ascertain its pollution status. The result of such checks should be communicated to inhabitants so that necessary precautionary measures would be taken by the users.
iv) It is also important to monitor the siting of wells especially with regard to potential sources of contamination. Wells should be protected and provided with facilities for the extraction of the water. High sanitary condition should be maintained around the well surroundings so as to reduce the introduction of coliform organisms into the water sources.
v) The government should coordinate sampling and monitoring programs required by zones, so as to check the pollution of groundwater since lots of people depend on this source for water supply.
vi) Laws should be enforced to protect and manage our water sources from being polluted. The laws should equally regulate the digging of boreholes in places otherwise not suitable for such facilities. General cleanliness and management of wells is needed because water is an index of development in any country, so existing sources must be protected.

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