WATER QUALITY ASSESSMENT AND THE DESIGN OF A CHLORINE DISINFECTANT SYSTEM FOR FUOYE, IKOLE CAMPUS

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ABSTRACT

Disinfection of water is a crucial step in the treatment of water in order to obtain clean drinking water. The use of water disinfection as a public health measure reduces the spread of diseases. This research paper examines water quality assessment of ground and surface water samples obtained from Ikole campus of the Federal University Oye-Ekiti (FUOYE). The obtained stream water was tagged Sample A, and the ground water (borehole) was tagged Sample B. These two constitute major source of water in the campus. Initial water quality assessment of the parameters that effect chlorine decay was done and compared with World Health Organization (WHO) and Nigeria Standard for Drinking Water Quality (NSDWQ) standard for chlorination. Examples of such parameter includes: temperature, pH, turbidity, coliform count etc. Predetermined initial concentration of 1.0 to 3 mg/l was added to different Jar and the contact time required to achieve a residual level of 0.2 to 5 mg/l was determined. Apart from the Jar test other chlorination related experiments done includes supernatant turbidity, chlorine decay and demand distribution. This study indicates sample A as having slower decay rate than sample B. This presents a chlorination assessment of FUOYE water useful for the development of a chlorine disinfection system for her use. Continuous monitoring of the water quality is necessary after the quality assessment is done resulting to water management. It was concluded that results from this work on laboratory conducted on surface water showed that it requires further treatment before it can be suitable for drinking water. It was recommended that there should be continuous testing of water quality composition of surface and groundwater in FUOYE Ikole campus water. Chlorine is highly recommended in terms of cost effectiveness (i.e. lower in cost) and readily available because of its wide array benefits which cannot be provided by any other disinfectant which includes ozone, ultraviolet radiation etc.

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DEDICATION

We dedicate this project to Almighty God who has been our source of guidance and provider throughout the years of study in the great institution and our wonderful families for all the love, care and support they have given us. We will be forever grateful.

CERTIFICATION

This is to certify that this project was prepared by Komolafe Funmileye (CVE/13/1062) and Salisu Aminat Abisola (CVE/13/1068) under my supervision and is approved for its contribution to knowledge and literary presentation. All sources of information are specifically acknowledged by means of references, in partial requirements for the award of Bachelor of Engineering (B.Eng.) degree in Civil Engineering, Federal University, Oye Ekiti, Ekti State, Nigeria.

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LIST OF ABBREVIATIONS

NSDWQ	Nigeria Standard for Drinking Water Quality
WHO	World Health Organization
CT	Chlorine disinfection
t	Contact time
TS	Total solids
TDS	Total Dissolved solids
TSS	Total suspended solids
NTU	Nephelometric Turbidity Unit
BOD	Biochemical Oxygen Demand

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CHAPTER ONE

INTRODUCTION

1.1 General Background

Water is the most important natural resource in the world since without it life cannot exist and most industries would not operate. Although human life can exist for many days without food, the absence of water for only a few days has fatal consequences. The presence of a safe and reliable source of water is thus an essential prerequisite for the establishment of a stable community. Water is a basic nutrient of the human body and is critical to human life (Kleiner, 1999).

The main objective of water supply systems is to provide consumers with drinking water that is sufficiently free of microbial pathogens. In addition to this requirement, water purification for domestic use must produce an aesthetically acceptable (in terms appearance, taste and odour) and chemically stable water (i.e. it must not case corrosion or form deposit in pipes. The key to produce water of such desired quality is to implement multiple barriers, which control microbiological pathogens, and chemical contaminants that may enter the water supply system.

Quality standard requirements for water differ in their uses, from drinking to washing, bathing and so on. Quality assessment of water is undoubtedly important as water being a universal agent is used every day, everywhere and by everybody. Since water quality issues are health related, hence, the need for the assessment. The term "water quality" describes the physical, chemical and microbiological characteristics of water. These properties collectively determine the overall water quality and the fitness of the water for a specific use. Water quality is only meaningful when evaluated in relation to the use of the water. The reason is that water of a certain quality may be fit for a specific use, but completely unfit for another use. Water quality should not only be assessed for drinking but should also meet adequate standards for its other uses as contact with contaminated water results in serious health hazards.

As described by Wallace et al. (2002), disinfection is the process of treating source water in drinking water treatment facilities by inactivating microorganisms. Disinfection is the process designed to kill or inactivate most micro-organisms in water essentially all pathogenic organisms. (Pennsylvania Department of Environmental Protection, 2016). This Microorganisms commonly associated with waterborne disease include: bacteria (e.g. *Escherichia coli, Vibrio cholerae*); viruses (e.g. Hepatitis A, poliovirus A); and protozoa (e.g. *Cryptosporidium, Giardia*). Chlorination is most effective against bacteria and viruses and least effective against protozoa (WHO, 2017). Water disinfection is a treatment aimed at reducing the presence of pathogenic microorganism in the water. To ensure microbiological quality disinfection treatment is of primary importance. Using disinfectants, pathogenic bacteria from the water can be killed and water made safe for the user.

The World Health Organization (WHO) provide the guidelines for drinking water quality in the protection of public health. The guidelines provide the recommendations for managing the risk from hazards that may compromise the safety of drinking water and provide a scientific point of departure for national authorities to develop drinking water regulations and standards appropriate for the national situation.

The disinfection treatments are divided in conventional, advanced and natural processes. The conventional technologies include chlorine, chlorine dioxide, ozone, peracetic acid and ultraviolet (UV) radiation. The advanced technologies include the combination of ozone and hydrogen peroxide, of ozone and UV radiation, of hydrogen peroxide and UV radiation, of UV radiation with titanium dioxide, membranes technologies, and processes that are being studied.

A chemical disinfectant that has been used effectively since 1850, is chlorine (sodium hypochlorite) (White, 1999). Chlorine has become the most widely used water treatment disinfectant because of its potency, ease of use and cost effectiveness (White, 1999). Chlorine reacts with water to form hypochlorous acid (HOCl) and hydrochloric acid (HCl) (Carlsson, 2003). The most common chemical disinfectant for water treatment, and the one that has historically made the greatest contribution to the prevention of waterborne disease worldwide, is chlorine (EPA, 2011). The typical forms of chlorination used in water treatment are Elementary Chlorine, Hypochlorite and Chlorine Dioxide. The concentration of elemental chlorine is 100% which comes in form of a liquid or gas. Sodium hypochlorite is the liquid form used in most water treatment plant and comes in concentration of 12.5 and 15%. Calcium hypochlorite is the solid form and is available in granules, pallets and powder forms (Pennsylvania Department of Environmental Protection, 2016). Chlorine is very reactive, volatile and corrosive substance, and its major strength property is that is produces residual which may remain in water after even after disinfection has occurred. (WHO, 2017).

Chlorination is the process of adding chlorine to drinking water to disinfect it and kill germs. Chlorination involves the adding a measured amount of chlorine so the levels are right in order to achieve water purification. It is a chemical disinfection method that uses various types of chlorine or chlorine-containing substances for the oxidation and disinfection of what will be the potable water source. Chlorine is a strong oxidizing agent and is the conventional chemical used for the disinfection and control of microorganisms in drinking water. Chlorine is used to disinfect wastewater in either gaseous form, or as hypochlorite salts. Chlorine is added to drinking water to destroy pathogenic (disease-causing) organisms. It is relatively inexpensive and provides a residual concentration in a distribution system. Today it is the most commonly used disinfectant in water treatment. The WHO drinking water standard states that 2 to 3 mg/l provides a satisfactory disinfection, and the maximum residual concentration of free chlorine allowed is 5 mg/l.

1.2 Problem Statement

The treatment and distribution of water for safe use is one of the greatest achievements of the twenty-first century. Where adequate water treatment is not readily available, the impact on public health can be devastating. Worldwide, about 1.2 billion people lack access to safe drinking water, and twice that many lacks adequate sanitation. As a result, the World Health Organization estimates that 3.4 million people, mostly children, die every year from water-related diseases. Cholera, typhoid fever, dysentery and hepatitis A kill over a thousand of people annually.

Waterborne diseases are caused by enteric pathogens such as bacteria (Escherichia coli, Vibrio cholera), viruses (Hepatitis viruses A and E) and parasites (Giardia) that are transmitted by the faecal oral route (Grabow, 1996; Leclerc *et al*., 2002; Theron and Cloete, 2002). Waterborne spread of infection by these pathogenic microorganisms depends on several factors such as: the survival of these microorganisms in the water environment, the infectious dose of the microorganisms required to cause a disease in susceptible individuals, the microbiological and physio-chemical quality of the water, the presence or absence of water treatment and the season of the year (Deetz *et al.*, 1984; Leclerc *et al.*, 2002; Theron and Cloete, 2002). Effect of water borne diseases is due to inadequate source to clean water; students source their water from impurity sources like well close to septic tanks, dump site etc. Even where water treatment is widely practiced, constant vigilance is required to guard against waterborne disease outbreaks. Well-known pathogens such as *E. coli* are easily controlled with chlorination, but can cause deadly outbreaks given conditions of inadequate or no disinfection. Some emerging pathogens such as *Cryptosporidium* are resistant to chlorination and can appear even in high quality water supplies.

1.3 Justification

Despite a range of new challenges, drinking water chlorination will remain a cornerstone of waterborne disease prevention. Drinking water chlorination and filtration have helped to virtually eliminate these diseases in the U.S. and other developed countries. The population of students in Ikole campus of the institution is increasing rapidly as more students are admitted yearly. Over the years, there has been a tremendous increase in the demand for safe water on campus due to rapid growth of population.

Chlorine's wide array of benefits cannot be provided by any other single disinfectant. While alternative disinfectants (including chlorine dioxide, ozone, and ultraviolet radiation) are available, all disinfection methods have unique benefits, limitations and costs. Water system managers must consider factors, and design a disinfection approach to match each system's characteristics and source water quality. In addition, world leaders increasingly recognize safe drinking water as a critical building block of sustainable development. Chlorination can provide cost-effective disinfection for remote rural villages and cities alike, helping to bring safe water to those in need.

1.4 Aim

This study is aimed at conducting a comprehensive assessment to water of samples collected from surface water(streams) and groundwater (well) obtained from Fuoye, Ikole campus and the design of a chlorine disinfect system for Fuoye.

1.5 Objectives

The specific objectives are:

1. To assess the physical, chemical and biological integrity of different water sources in Ikole-Campus of Federal University Oye- Ekiti.
2. To evaluate and compare the performance and effectiveness of chlorine in water treatment systems.
3. To design a disinfection system for water treatment in Ikole-Campus of FUOYE.

1.6 Scope of Works

This research work is limited to water quality assessment and chlorine disinfectant system with the physiochemical analysis, chlorine decay test and some other test. The test results are used to assess water quality and chlorine disinfectant with references standards like WHO and NSDWQ on the samples.

CHAPTER TWO

LITERATURE REVIEW

2.1 General Background

Water is a precious natural resource vital for sustaining life. It is in a continuous circulation movement (i.e., hydrological cycle), and is not uniformly distributed in time and space. Due to its multiple benefits and the problems created by its excesses, shortages and quality deterioration, water, as finite resource requires special attention (Pinderhughes, 2004). Water is considered to be a finite global resource. Water permeates all aspects of life on earth and water is one of the most important necessity of life, without which there will be no existence on Earth. It is identified as one of the most important natural resources because it is viewed as a key to prosperity and wealth (Arbués *et al.*, 2003).

2.1.1 Water Treatment

Water treatment usually comprises water clarification and disinfection processes (Suarez *et al.*, 2003). In conventional water treatment a series of processes including coagulation, flocculation, sedimentation, filtration and disinfection are often used (AWWA, 1990). A combination of several processes is usually needed to improve the quality of raw water depending on the type of water quality problems present, the desired quality of the treated water, the costs of different treatments and the size of the water system (Kalibbala, 2007). The purpose of water treatment is to reduce or remove all contaminants that are present in the water and to improve water quality so that it is completely safe to drink. Water is unlikely to be completely free of contaminants at the original source. The types of water treatment processes depend on the characteristics of the raw water (untreated water direct from its source) and required water quality standards. Suspended solids, bacteria, algae, viruses, fungi, minerals such as iron and manganese, are among the substances that are removed during water treatment. Effective treatment should ensure the removal of all disease-causing agents and so reduce the possibility of the outbreak of waterborne disease.

Disinfection is important because the turbidity removal by sedimentation and filtration does not remove all microbial pathogens from water. The disinfectant residual in the drinking water distribution system is also one of the key factors controlling the microbial quality of water, preventing bacterial proliferation in the water phase (regrowth) and limiting viability of bacteria released from pipe wall biofilms (Momba and Makala, 2004). It offers a reliable reduction of pathogenic microorganisms at reasonable operating costs. There are, however, various methods that can be used for disinfection. These include physical processes (e.g. ultraviolet radiation) and chemical processes (e.g. Chlorine dioxide, Bromine, and Ozone) (Metcalf and Eddy, 1991; Lim *et al.*, 2010).

The practice of disinfection of water supplies has been, in general, used since the beginning of the century and has given rise to substantial reduction in the occurrence of water-related diseases. The most commonly used technology to achieve disinfection has been chlorination. This method of disinfection has been proved to be reliable, appropriate and effective worldwide (Solsona and Pearson, 1995).

Various literature sources mention that the following factors have to be considered when applying disinfection agents (Metcalf and Eddy, 1991; AWWA, 2002; White, 1999; Charrois and Hrudey, 2007): contact time, disinfectant concentration and type, number and age of organisms, type of organism, constituents in the effluent, temperature, chlorine demand and mixing.

There is a wide range of disinfectants used in water treatment. These include chlorine, chlorine dioxide, chloramines, ozone and ultraviolet irradiation. The most commonly used disinfectant for water treatment is chlorine (Karlin, 1995). The most common chemical disinfectant for water treatment, and the one that has historically made the greatest contribution to the prevention of waterborne disease worldwide, is chlorine (EPA, 2011).

Chlorination is one of the most widely practiced public health forms of disinfection in the developed world and according to Karlin (1999), it is credited with reducing cholera incidence by 90%, typhoid by 80% and amoebic dysentery by 50% in the United States. Although, chlorination is commonly used in the majority of South African rural water treatment plants, recent studies have shown that these plants do not produce the quality or quantity of drinking water that they were designed to produce (MacKintosh and Colvin,2002; Momba *et al.*, 2004a; 2004b).

2.2 Characterization of Domestic Treatment Processes

The processes involved in removing the contaminants include physical processes such as settling and filtration, chemical processes such as disinfection and coagulation and biological processes such slow sand filtration.

2.2.1 Physical treatment methods

Physical treatment methods include boiling, heating, settling, filtration and exposure to ultraviolet radiation from sunlight (Gilman and Skillikorn, 1985; Mintz *et al.*, 1995; Conroy *et al.,* 1996; CDC, 2001; Sobsey, 2002).

Boiling is widely used since it is easy to use and effective in destroying bacteria, viruses and protozoa in all types of water. Sedimentation and settling is used for very turbid water. The turbidity is usually due to the presence of sand particles (mud). After the water is collected, the container is left undisturbed for a few hours (Sobsey, 2002). The large dense particles (sands and silts) together with large microorganisms will settle out (sediment) due to the effect of gravity. The upper cleaner water is carefully removed without disturbing the sedimented particles. Unfortunately, sedimentation is not very effective in reducing microbial pathogens in stored household water (Sobsey, 2002).

Filtration is a widely used method to remove particles and some microorganisms from water samples (Potgieter, 1997; Sobsey, 2002). Several types of filter media and filtration processes are available for household treatment of water. However, the effective removal of microorganisms, the cost and the availability of the filter media in developing countries varies from easy to moderate to difficult (Sobsey, 2002).

2.2.2 Chemical treatment methods

Various chemical methods are available for the treatment of drinking water at the household level and include methods such as coagulation-flocculation, precipitation, adsorption, ion exchange and chemical disinfection with agents such as sodium hypochlorite (Gilman and Skillicorn, 1985; Mintz *et al.*, 1995; Conroy *et al.,* 1996; CDC, 2001; Sobsey, 2002).

2.2.2.1 Coagulation

Coagulation is the process by which the medium is destabilized such that particle are readily agglomerated. It is the process of chemically changing colloids, allowing them to form bigger particles by particle destabilization. The transformation from stable to unstable state is visible. In dispersed suspensions, floc or precipitate, formation can be observed due to destabilization whereas in more concentrated suspension dewatering of the suspension is observed. Particle destabilization is achieved by double layer compression or physical enmeshment of colloids within the coagulant precipitates or via a chemical reaction or through chemical sorption (Cornwell and Bishop, 1983).

Coagulants are widely used in water treatment systems but are not commonly used at conventional acidic drainage treatment operations. The most common coagulants are aluminium and iron salts. Aluminium and iron coagulants react with bicarbonate alkalinity (HCO3-) in acid drainage, creating aluminium, ferric or ferrous hydroxide flocs which attract metals in solution through coprecipitation (Faust and Aly, 1999).

Shahin et al. (2010) presented a study about the performance of the coagulants poly-aluminum chloride and aluminum sulphate in leachate treatment. The coagulation study was analysed by the author. The coagulation test was carried out to remove chemical oxygen demand, colour, total suspended solids and turbidity.

Another coagulation control in water treatment process for drinking water which uses artificial neural network was discussed by Nicolas and Thierry (2001). The author has mentioned that modelling of water treatment using traditional method is difficult due to the complex chemical and physical phenomena. This study also showed that the water treatment process is nonlinear. The authors stressed the need for treated water parameters model mainly to know the treated water turbidity and it was concluded that the performance depends purely on the quality of training data. Kathy et al. (2005) presented his article about the water treatment in cold region for contaminated water. This research concentrated on coagulation experiments and modelling methods for the water treatment process. The water quality parameters considered were pH, coagulant dosage and flow rate. This research showed that a simple laboratory set up could be used to predict the full-scale water treatment process performance. The authors suggested that the laboratory set up can be tested in different operating conditions without affecting the real process.

2.2.2.2 Flocculation

Flocculation is the process that follows on from destabilization and forms aggregates ((i.e. flocs). Flocculation is the process of linking coagulated colloids in to contact with each other to form larger aggregates (Gregory et al., 1997). This is generally considered to be a two stage process of particle transport and particle attachment (Amirtharajah and O'Melia, 1990). Infact flocculation occurs as soon as a coagulating agent is added (Bratby, 2006).

Flocculation involves the combination of small particles by bridging the space between particles with chemicals (Skousen *et al.*, 1996). Essentially, coagulants aid in the formation of metal precipitate flocs, and flocculants enhance the floc by making it heavier and more stable. For this reason, flocculants are sometimes referred to as coagulant aids at water treatment operations (Tillman, 1996; Faust and Aly, 1999).

According to Sajad et al., (1998) the quality of groundwater is a function of natural processes as well as anthropogenic activities, and that the type, extent and duration of anthropogenic activities on groundwater quality are controlled by the geochemical and physical processes and the hydrological condition present (Matthess,1976).

2.2.2.3 Chemical disinfectant

Chemical disinfectant agents have proved to be the most successful types of treatment and include free chlorine (which will be discussed in more detail), chloramines, ozone and chlorine dioxide (Sobsey, 2002).

Several factors might play a role in the effectiveness of a chemical disinfectant. These factors include pH, turbidity, temperature, degree of microbial contamination and the contact time of the disinfectant to the water and microorganisms (LeChevallier *et al.*, 1981; Reiff *et al.*, 1996). A chemical disinfectant that has been used effectively since 1850, is chlorine (sodium hypochlorite) (White, 1999).

Chlorine has become the most widely used water treatment disinfectant because of its potency, ease of use and cost effectiveness (White, 1999). Chlorine reacts with water to form hypochlorous acid (HOCl) and hydrochloric acid (HCl) (Carlsson, 2003). The free residual chlorine can also kill the microorganism by disrupting the metabolism and protein synthesis, to decrease respiration, glucose transport and adenosine triphosphate levels and to cause genetic effects by modification of the purine and pyirimidine basis (LeChevallier and Au, 2004).

2.2.3 Biological treatment methods

2.2.3.1 Slow sand filtration

Slow sand filtration is essentially a biological process whereby water passes slowly downwards through a bed of fine sand at a steady rate. Removal of colloidal matter, microorganisms and colour by means of slow rate filtration through a sand bed on which a layer of colloidal matter and micro-organisms is allowed to form.

2.3 Domestic Water Supply

These include water supplied for domestic purposes. Water uses in homes are for the purpose of: washing, cleaning, bathing, drinking flushing, gardening etc. These consume a large portion of water and important factor in the determination of water demand within a network node. In Nigeria, water is generally supplied for domestic purposes through well, boreholes, and streams. These sources are susceptible to pollution and infection if not well protected.

2.4 Typical Municipal Water Quantity

The quantity of water delivered and used is an important aspect of domestic water supplies, which influences hygiene and therefore public health. (WHO, 2003), review the requirements for water for health-related purposes to derive a figure of an acceptable minimum to meet the needs for consumption (hydration and food preparation) and basic hygiene, this water needs to be of a quality that represents a tolerable level of risk. This volume does not account for health and well-being-related demands outside normal domestic use such as water use in health care facilities, food production, economic activity or amenity use. The basic need for water includes water used for personal hygiene, but defining a minimum has limited significance as the volume of water used by households depends on accessibility as determined primarily by distance and time, but also including reliability and potentially cost.

The importance of adequate water quantity for human health has been recognised for many years and there has been an extensive debate about the relative importance of water quantity, water quality, sanitation and hygiene in protecting and improving health (Cairncross, 1990; Esrey *et al.*, 1985; Esrey *et al.*, 1991). Despite this debate, international guidelines or norms for minimum water quantities that domestic water supplies should provide remain largely lacking. The WHO/UNICEF Joint Monitoring Programme, which produces the Global Assessment of Water Supply and Sanitation data, describe reasonable access as being 'the availability of at least 20 litres per person per day from a source within one kilometre of the users dwelling'(WHO and UNICEF, 2000). However, it should be noted that this definition relates primarily to access and should not necessarily be taken as evidence that 20 litres per capita per day is a recommended quantity of water for domestic use.

A similar figure has been suggested by other researchers (Carter *et al.*, 1997). Gleick (1996) suggested that the international community adopt a figure of 50 litres per capita per day as a basic water requirement for domestic water supply. Poor hygiene may in part be caused by a lack of sufficient quantity of domestic water supply (Cairncross and Feachem, 1993). The diseases linked to poor hygiene include diarrhoeal and other diseases transmitted through the faecal-oral route; skin and eye diseases, in particular trachoma and diseases related to infestations, for instance louse and tick-borne typhus (Bradley, 1977; Cairncross and Feachem, 1993).

The relative influence of consumption of contaminated water, poor hygiene and lack of sanitation on diarrhoeal disease in particular has been the topic of significant discussion (Esrey *et al.*, 1985). This has mirrored a broader debate within the health sector worldwide regarding the need for quantifiable evidence in reducing health burdens. The desire for evidence-based health interventions is driven by the need to maximise benefits from limited resources (a critical factor both for governments and their populations). It is also driven by the desire to ensure that populations benefit from the interventions that deliver the greatest improvement in their health.

Table 2.1: Water Consumption per Person per Day (Pitter,2009)

Usage	**Person $l.d^{-1}$**
Drinking and cooking	4-8
Personal hygiene	8-12
Bathing, showering	30-60
Dishwashing	8-20
Laundry	14-20
Flushing toilet	30-45
Treatment	4-8
Miscellaneous	6-12
Total	**104-185**

According to Table 2.1. The water consumption ranges between104–185 litre per person per day. The above stated indicative information will enable evaluation of water quality and supply.

2.5 Water Resources

Water resources are of three types, surface water, ground water and rain water. It is important to distinguish between them, since their quality differs and the method needed to protect them also differ.

Ground water (hand-dug wells, bore-holes) surface water (rivers, streams, ponds), precipitation (rain-water, snow) and springs are the main source of water available to the people in general. The qualities of these water bodies vary widely depending on the location and environmental factors (Tay,2007).

2.5.1 Surface water resources

Surface water resources are about the water bodies which are in direct contact with the atmosphere. For example, rivers, lakes, oceans, springs and waterfalls, are all surface water resources. Surface water bodies are also in direct contact with contaminants with land use. When rain falls over the earth surface, it carries with it any pollutants and part of that finally finds its way into a nearby water body.

2.5.2 Ground water resources

Ground water resources are water which are located well below the ground surface. Groundwater are protected temporarily from pollutants by the top soil layer between it and the ground surface. Ground water include hand dug wells, boreholes.

Groundwater begins with rain and snow that seeps into the ground. The amount of water that seeps into the ground varies widely from place to place according to the land surface that is present in porous surface materials that water readily seeps through, about 20% of the rain and snowmelt may seep into the ground. In less porous surface material, where seepage is much slower, perhaps 5% will seep into the ground. The remainder of the rain and snowmelt runs off the land surface into streams or returns to the clouds by evaporation. Groundwater seepage is also strongly influenced by the season of the year. Evaporation is greater during the warm months, the ground surface may be frozen, hindering water seepage, and evaporation is less (Lyle S., and Raymond Jr. 1988).

Groundwater quality in a region is largely determined by both natural processes (dissolution and precipitation of minerals, groundwater velocity, quality of recharge waters and interaction with other types of water aquifers) and anthropogenic activities (Andrade et al.2008; Devic et al. 2014).

2.6 Water System: A Global Problem in Tertiary Institutions

Water supply source has to be both adequate and reliable for the place to be served. A water system has two primary requirements: First, it needs to deliver adequate amounts of water to meet consumer consumption requirements plus requirements for construction of structures. Second, the water system needs to be reliable; the required amount of water needs to be available 24 hours a day, 365 days a year (Hickey, 2008).

Water sources need to be selected carefully to make sure that this fundamental requirement is met. Two main factors that affect water supply selection are:

i. Quality of water: Water must be treated or purified to meet the World Health Organisation (WHO) Standard.
ii. Quantity of water: The quantity of water must be adequate to meet consumer consumption at any time of the day, day of week, and week of the year. (Hickey, 2008).

2.7 Water Quality

According to Kolo (2009), groundwater usage is based on the postulation that groundwater, being precluded from the atmosphere, is less susceptible to pollution. However, groundwater is sometimes known to be vulnerable to quality problems that may have serious impact on human health. But water, which is the most precious natural, needed for life after oxygen and "key" to health, should be qualitative before being used (Umara et al 2007). The quality of water varies with its purpose, thus the quality required for it is therefore affected by landfill of solid wastes from domestic, industrial and irrigation purposes. Polluted waters, irrespective of the pollutants, when consumed, may lead to variety of diseases, such as cholera, typhoid, dysentery, skin and mental disorders, etc. The quality of water that is consumed is well-recognised as an important transmission route for infectious diarrhoeal and other diseases (WHO, 1993). The importance of water quality continues to be emphasised by its role in epidemics and contribution to endemic disease from pathogens (Ford, 1999; Payment and Hunter, 2001).

Going by popular perception, water, which is sweet and free from odour, colour and organic and inorganic contamination, is considered as safe drinking water. Drinking water quality has been determined by the presence of certain organic and inorganic substances in excess of tolerance limits.

2.8 Chlorine Disinfectant

Chlorine is widely used in emergency response because of its availability, ease of use, cost-effectiveness, ease of verification, efficacy in inactivating bacterial and viral pathogens, and maintenance of a chlorine residual in treated waters that protects against recontamination during storage of water (Lantagne and Clasen, 2012b). Chlorine is very reactive, volatile and corrosive substance, and its major strength property is that is produces residual which may remain in water after even after disinfection has occurred. (WHO, 2017). Chlorine is very reactive and combines with any oxidizable substrate to form secondary compounds, such as trihalomethanes (IFPA, 2001).

The most common forms of free chlorine include liquid chlorine and hypochlorites. The inhibitory or antimicrobial activity of chlorine depends on the amount of hypochlorous acid (free chlorine) present in the water that comes into contact with the microbial cells. Hypochlorous acid is the form of available free chlorine that has the highest bactericidal activity against microorganisms (Sapers, 2003). The effects of pH on chlorine dissociation indicate that at pH 7.5 or greater the quantity of chlorine available as active hypochlorous acid (HOCl) is limited, rather, chlorine exists mainly as inactive hypochlorites (OCl^-). If the pH of the wash water decreases below 4.0, then chlorine gas may be formed which is a health hazard for employees (IFPA, 2001). Therefore, the pH of the water should be maintained between 6.0 and 7.5 to ensure adequate and safe chlorine activity. The percentages of chlorine as HOCl at pH 6.0 and 8.0 are about 97% and 23%, respectively (WHO, 1998).

According to Richardson et al (2007), if the water contains a lot of decaying materials, free chlorine can combine with them to form disinfection- by products like tribhalomethanes. Though there is a limit to the use of chlorine as negative results are possible with the addition of too odour in water are often enhanced. Rideal et al, (2005) suggests that this is because chlorine reacts quickly with other substance in after (and forms combined chlorine) or escapes as a gas into the atmosphere. The free chlorine test measures only the amount of free or dissolved chlorine in water, but the total chlorine test measures both free and combined of chlorine. Buffle et al. (2004) were able to determine that the use of chlorine along with ammonia in prechlorination before ozonation helps to reduce the formation of bromate.

Fair et al, (2000) states that less than one half (0.5mg/l) of free chlorine is needed to kill bacterial without causing water to smell or taste unpleasant. Most people cannot detect the presence of chlorine on water amount (1.0mg/l), although 1.0mg/l chlorine in water is not harmful to people, it does cause problems to fish and other aquatic animals when they are expose to it over a long period of time. It is very important for water suppliers to monitor closely the level of chlorine present in the water (Hodges 1997).

Chlorine is a greenish- yellow gas that dissolves easily in water. It has a pungent, noxious colour that some people can perceive smell at concentrations above 0.3 part million. Chlorine is an excellent disinfectant commonly added to drinking water supplies to kill harmful microorganism. Chlorine is not only an effective disinfectant but it also reacts with ammoniamiron and other metals and some organic compounds to improve overall water quality (White 2000).

Dai *et al.*, (2013) found that the monitoring results of their study showed that better instantaneous mixing at the chlorine injection point reduced the effect of chlorination/dechlorination on 5-day BOD levels. The results of these studies show a wide range of inactivation kinetics, with the potential for the contact time (Ct) and the disinfectant dose applied to the contactor to be reduced while not compromising on disinfection efficiency. It is also shown that the physical mixing of the disinfectant (chlorine) with the water to be treated was essential in ensuring adequate disinfection.

Presently, the extensive use of chlorine-based disinfection has a range of advantages, including ease of handling, measurement and control, low cost of installation and, most importantly, the controlled concentration of chlorine residual after treatment (Rauen *et al.*, 2012). Due to chlorine's efficiency and relatively low capital demand, many wastewater treatment plants have applied chlorination for disinfection of treated wastewater before discharging it. However, determination of optimal doses of chlorine for chlorination and sulphite for dechlorination, which removes residual chlorine, should guarantee complete destruction of microorganisms in treated wastewater and should protect aquatic life in a receiving stream from toxic effects of active residual chlorine (Kim *et al*, 2006; MacCrehan, *et al.*, 2005).

2.8.1 Properties of chlorine

Chlorine exists as a solid (e.g. powder), liquid or gas. Key properties of chlorine with relevance to drinking-water disinfection include the following:

1. Chlorine is very chemically reactive, reacting with, for example, organic material, microorganisms, metals, pipe material and pipe fittings;

2. Chlorine liquid is volatile, meaning once exposed to air, the chlorine may be lost from the water phase and go into the air;
3. Chlorine has a distinctive, characteristic taste and odour, which may be detected by individuals when smelling or drinking the water;
4. Chlorine is corrosive, meaning it can cause severe irritation and chemical burns to human tissues such as skin, as well as damaging material such as pipes; as such, chlorine must bestored and handled carefully;
5. Chlorine may remain in the water after disinfection has occurred; this may protect drinking water from recontamination by harmful microorganisms during storage and distribution to the consumer (Principles and Practices of Drinking-water Chlorination (WHO,2017).

2.8.2 Principles of Chlorination

Chlorination Principles describe key chlorination concepts useful for the implementation of effective chlorination practices (WHO, 2017). Principles of chlorination are outlined below:

2.8.2.1 Chlorine dose

The chlorine dose refers to how much chlorine is added to the drinking-water (or, the concentration of chlorine in the drinking-water).

2.8.2.2 Chlorine decay

Chlorine decay means the decrease (or reduction) in the concentration of chlorine in drinking water as it passes from the water treatment plant through to the end of the distribution system.

2.8.2.3 Chlorine demand

Casey et al., (2012*)* defined chlorine demand as the reduction in residual free chlorine with contact time due to its reaction with various constituents in the water. The total amount of chlorine which will react with both compounds like iron and manganese and with organics and ammonia is referred to as the chlorine demand.

Chlorine demand is defined as the difference between the initial chlorine concentration and the chlorine residual after a specified contact time, t (or as C_0–Ct, where C_0 is the initial free chlorine concentration and Ct is the free chlorine concentration at contact time (t) (Helbling and Van Briesen, 2007; Winward *et al.*, 2008).

Chlorine demand is the difference between the amount of chlorine added to the water (the chlorine dose) and the total chlorine detectable in the water. The chlorine demand for some waters, for instance some river waters, can increase dramatically, particularly after heavy rain.

Chlorine demand increases with time, and can be mathematical expressed

Chlorine demand = Initial Chlorine Dosage □趴□ - Residual Free Chlorine (RFC) (2.1)

2.8.2.4 Chlorine residual

Chlorine persists in water as 'residual' chlorine after dosing and this helps to minimize the effects of re-contamination by inactivating microbes which may enter the water supply after chlorination. It is important to take this into account when estimating requirements for chlorination to ensure residual chlorine is always present. The level of chlorine residual required varies with type of water supply and local conditions. The chlorine residual should generally be in the range 0.2 to 0.5 mg/l of chlorine in treated water. In water supplies which are chlorinated there should always be a minimum of 0.5mg/l residual chlorine after 30 minutes contact time in water.

2.8.2.5 Breakpoint chlorination

Breakpoint chlorination is a phenomenon in which all the ammonium ions disappear and the solution possesses free chlorine residue. It occurs when the molar ratio of chlorine to ammonia is greater than 1.0. Under ideal conditions, at breakpoint chlorination, the reduction of chlorine and oxidation of ammonia occurs at a 2:1 ratio. Further addition of chlorine results in more and more free available chlorine. This phenxomenon is very important in calculating the chlorine dosage to maintain the chlorine residue in contact with microorganism for effective inactivation (Marhaba, 2009 & Fisher *et al.*, 2011).

Figure 2.1 shows the curve for chlorine dosage vs. chlorine residue to explain the phenomenon of breakpoint chlorination.

1. Stage 1: Chlorine is reduced to chlorides by metallic ions and compounds that are oxidized easily (Fe2+, H2S, etc.).
2. Stage 1 and Stage 2: Chlorine reacts with ammonia to form chloramines, which are weak disinfectants.
3. Stage 2: The nitrogen trichloride formation reaction is favoured and the chloramines are consumed in the reaction with free chlorine. In this zone, nitrogen gas is formed, which leaves the system and breakpoint chlorination is reached.
4. Stage 3: Free chlorine residue is observed in water and further addition of chlorine only increases the residue concentration.

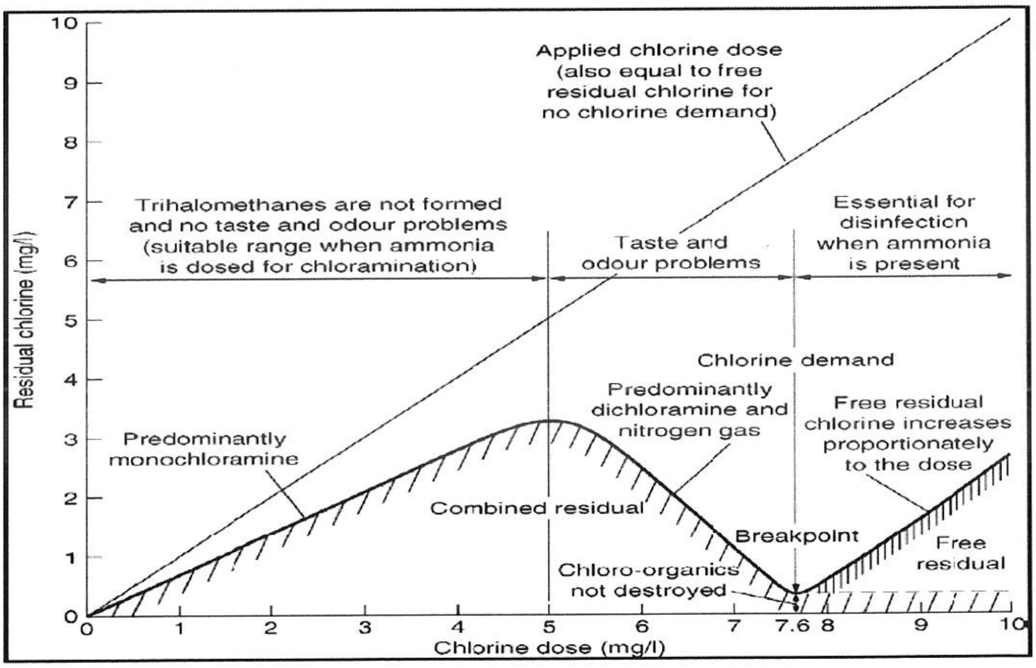


Figure 2.1: Theoretical breakpoint chlorination (Marhaba, 2009).

2.8.2.6 Residual Free Chlorine (RFC)

A chlorine residual is a low level of chlorine remaining in water after its initial application. Free chlorine is the chlorine portion available for disinfection after chlorine demand is satisfied and combined chlorine is formed. This is the strongest from of residual chlorine (Wiant, 2013; Pennsylvania Department of Environmental Protection, 2016).

2.8.2.7 Contact time

Contact time is perhaps the most important of all the factors that influence the disinfection process. In any given concentration of disinfectant, the degree of disinfection achieved is directly proportional to the contact time (Marhaba, 2009, Lenntech, 2012). That is, the extent of inactivation is greatly affected by the duration of exposure of microorganisms to disinfectants (Kim *et al.*, 2013). Disinfection with chlorine is not instantaneous. Time is required in order that any pathogens
present in the water are inactivated.

2.8.2.8 CT disinfection

CT is simply the concentration of chlorine in your water times the time of contact that the chlorine has with water (Rush, 2002). The chlorine concentration is determined by measuring the residual chlorine in a water sample. This can be expressed mathematically as

$$CT = \text{Residual Free Chlorine (RFC)} \times \text{Contact Time (t)} \qquad (2.2)$$

2.8.2.9 Log removal value (LRV)

A log removal value (LRV) is a measure of the ability of a treatment processes to remove pathogenic microorganisms which are applied to each collective 'group' of pathogens (i.e. LRV for virus, LRV for bacteria, etc.) (Water Reaserach Australia, 2014; USEPA, 2012).

$$\text{[illegible]} = \text{[illegible]}\left[\frac{\text{[illegible]}}{\text{[illegible]}}\right] \qquad (2.3)$$

2.9 Other Disinfectant Methods

2.9.1 Ultraviolet radiation

UV disinfection has been applied in European drinking water treatment since the mid 1950's (Kruithof et al., 1992). This form of disinfection is being used in ground water treatment plants in Europe to destroy *E.coli*, and *Aeromonas* bacteria. It has also been in use for several years to treat domestic wastewater and house water in North America (Parrotta and Bekdash, 1998). The UV technology is regarded as safe, easy to use, and free of chemicals. UV irradiation has been proved by Sundstrom et al. (1990), to destroy microorganisms and also decompose organic contaminants such as benzene. The disinfection of treated wastewater via ultraviolet (UV) radiation is a physical process that principally involves passing a film of wastewater within close proximity of a UV source (lamp).

UV disinfection is a process that instantaneously neutralizes microorganisms as they pass by ultraviolet lamps submerged in the effluent. UV disinfects water containing bacteria and viruses and can be effective against protozoans like, Giardia lamblia cysts or cryptosporidium oocysts. In the UV disinfection process, water is purified as it runs through a stainless-steel chamber (also called a "reactor") that contains a special UV- producing lamp. As the water flows past the lamp, the microbes in the water receive a lethal dose of UV. The source of UV radiation is the mercury arc lamp. Variations of the lamp exist, primarily related to the lamp's operating pressure.

Darby et al., (1995) showed the relative effectiveness of UV disinfection for selected microorganisms reported the resistance of microorganisms to chlorine and UV varies, a suitable indicator of performance between the two processes is lacking for more resistant forms. In general, however, both disinfectants are highly effective, with UV showing a greater proficiency against viruses, spores, and cysts.

Blatchley et al., (1996) reports UV irradiation to be a less expensive alternative than chlorination-dechlorination both in terms of capital and operating costs, for facilities where new construction is required. Where existing, functional chlorination facilities are in place (avoiding construction costs for a new chlorine contact chamber), UV is likely to be a more expensive alternative.

2.9.2 Ozonation

Ozonation is a chemical water treatment technique based on the infusion of ozone into water. Ozone is a strong oxidant and a potent disinfecting agent. Ozone is a strong oxidant and a potent disinfecting agent. Ozone is generally colorless and less soluble in water, with special pungent odor at ordinary temperature, from which its name was derived (Guzel-Seydim et al. 2004). Ozone is the strongest oxidant and it also provides control over taste- and odour-producing compounds such as methyl isoborneol and geos-min. Use of ozone as a disinfection agent is becoming increasingly common (Marhaba, 2009).

On the other hand, ozone is a chemical reactive reagent exhibiting electrophilic and nucleophilic characteristics, which are closely related to its resonance structures. Ozone has also been extensively applied for further treatment of industrial wastewater such as cyanide containing wastewater, cooking wastewater, oil refining wastewater, and pharmaceutical wastewater, through the selective oxidative reactions with unsaturated and conjugated matrix components (Laera et al., 2012, Chen et al., 2014a, Lin et al., 2014a).

Ozone disinfection is generally used at medium to large sized plants after at least secondary treatment (EPA, 1999). Although ozone treatment is able to achieve higher levels of disinfection compared to its competitors, it is often used sparingly. This is because ozone treatment as a disinfection option tends to have higher maintenance expenditure and capital costs as compared to its competitors. Also, ozone can be viewed as the most powerful oxidizing and disinfecting agent that is available for pool and spa water treatment (World Health Organization, 1993). Ozone is additionally being used in multiple industrial, municipal, and residential water systems. These include potable water, wastewater, process water, and semi-conductor applications (BCC Research, 2015).

CHAPTER THREE

METHODOLOGY

3.1 Research Overview

The research work was conducted in Ikole campus, Federal University Oye-Ekiti and whereby the water sample were taken from a stream (close to agricultural farm) and borehole (close to school hostel). After collection, samples were stored in sample container. The sample was then taken to the laboratory where it was tested. The sample was put into a beaker to test for turbidity, pH, temperature was taken again and some were stored in the refrigerator to test for the BOD and so on. All test was performed according to World Health Organization (W.H.O). The test carried out on each sample was physical tests (i.e. Color, Taste, Temperature), chemical tests (i.e. pH, turbidity, alkalinity, conductivity, total solids, total suspended solids, total dissolved solids, Biochemical Oxygen Demand (BOD), dissolved oxygen DO), biological tests (i.e. total coliform count, total bacteria count), residual chlorine, Jar test, Diethyl Paraphenylene Diamine DPD, chlorine decay test. The results will be compared to the standard specified values and grouped in accordance with World Health Organization (W.H.O) standards and Nigerian Standard for Drinking Water Quality (NSDWQ) respectively.

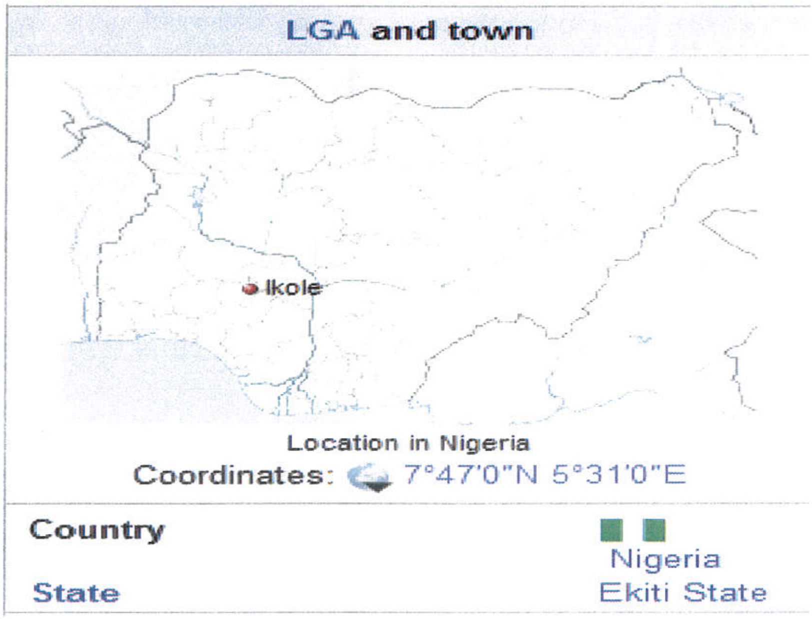
3.1.2 Sources of water

Plate 3.1: Stream water

Plate 3.1.2: Borehole water

3.2 Study Area

Geographically, Ikole Local Government area of Ekiti State, Nigeria is entirely within the tropic. It is located between longitude 5°31′0″E, East of Greenwich and latitude 7°47′0″N, North of the Equator as shown in the Fig. 3.1. The local government is mainly on the upland zone rising to about 250 metres above the sea level. The Local Government occupies an area of about 374,940kms of land and according to the 2006 National Population Census figure, the total population of the local government was 168,436.



LGA and town

Location in Nigeria

Coordinates: 7°47'0"N 5°31'0"E

Country	Nigeria
State	Ekiti State

Figure 3.1: Ikole-Ekiti on the map of Nigeria

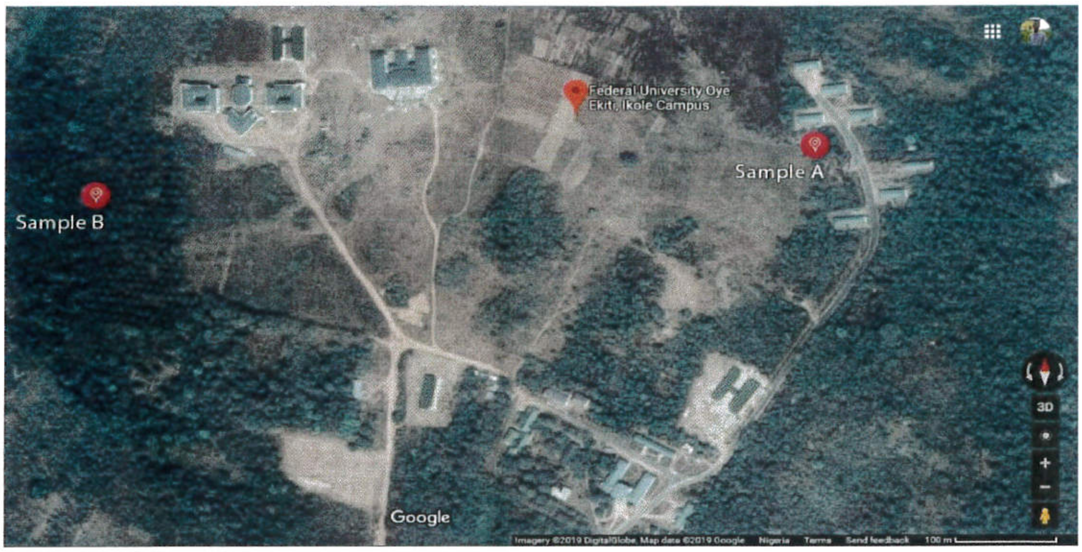


Plate 3.2: Sample location points on Google map

3.2.1. Sample collection

Samples was sourced from surface water (streams) and ground water (bore-holes) being the main source of water available to the Federal University Oye-Ekiti, Ikole Campus. pH, temperature was observed on site using the pH meter and thermometer.

Plate 3.2.1: Stream source

Plate 3.2.2: Borehole source

3.3 Preliminary Investigations

3.3.1 Sampling and analytical methods

The water quality which could be obtained by carrying out different laboratory tests to determine the different water parameters embedded therein. The different parameters were measured before and at different stages of the treatment processes. Turbidity were measured in the laboratory within two hours of obtaining samples. Colour, odour and taste, temperature, pH was measured at the site where the samples were obtained. Total and free chlorine were measured 10 min. after taking samples.

3.3.2. Apparatus and instruments used

The apparatus and instrument used: Beakers, sample bottles, label markers, sample storage containers, turbidity meter, pH meter glass thermometer, jenway conductivity meter, evaporating dish, cuvette, desiccator, UV spectrophotometer, petri dish.

3.4 Experimental Investigation

3.4.1 Turbidity

This test is done to determine the turbidity of the water sample i.e. the clarity of water. Turbidity is the measure of the water's ability to scatter and absorb light. High turbidity levels can reduce the efficiency of disinfection by creating a disinfection demand. Turbidity is measured in Nephelometric Turbidity Units (NTU), using a turbidity meter (USEPA, 1995). For effective disinfection, median turbidity should be below 0.1 NTU although turbidity of less than 5NTU is usually acceptable to consumers (WHO, 2004).

Procedure

The turbidity meter was powered on and standardized using the 0.02 NTU Reference Standards.

a) Stir the sample to disperse the solids, and allow air bubbles to disappear before dispensing it into a cuvette.
b) The sample was agitated to re-suspend any heavier particles without introducing air bubbles. The cuvette was filled with the aliquot of the sample. the cap was placed on the cuvette and condensation from the outside of the cuvette was carefully cleaned with a lint free wiper.

c) Place the sample cuvette into the well, align with the locator pin on the optical well, and take the NTU reading directly from the display.

d) The appropriate display range for best resolution was selected and the reading from the turbidity meter was taken within 3-5 seconds.

Plate 3.3: Turbidity meter

3.4.2 Temperature

It is determined using temperature meter (Hach, 2000). Temperature has implications on the usefulness of water for various purposes. Generally, users prefer water of uniformly low temperature plays a very important role in physical-chemical and biological behavior of aquatic system. It can also impact on palatability of water (WHO, 2006). Higher temperatures have encroached growth of microorganism and may increase taste, odour, colour and corrosion problems.

Procedure

This was carried out in mercury glass thermometer. The thermometer was placed in a beaker containing the water samples and the reading was recorded.

Plate 3.4: Thermometer

3.4.3 pH

This test is done to determine the acidity or alkalinity of the sample. pH is the process of analyzing the acidity or alkalinity of a solution. The pH of most drinking water lies within the range of 6.5 – 8.5 (WHO, 2004). Usually it has no direct impact on consumers and it is one of the most important operational water quality parameters (WHO, 2006). Water sample with low pH attributed to discharge of acidic water into these sources by agricultural and domestic activities. In fact, 98% of all world groundwater are dominated by Ca_2^- and HCO_3^- due to limestone weathering in the catchments and under groundwater beds (Brian, 2012).

Procedure

a. The pH of the water samples was determined using a pH meter.
b. Standardize the pH with buffer solution of pH 9 and later pH 4 for calibration of the pH meter.
c. The electrode was then dipped into the sample after calibration of the instrument and the reading was taken.

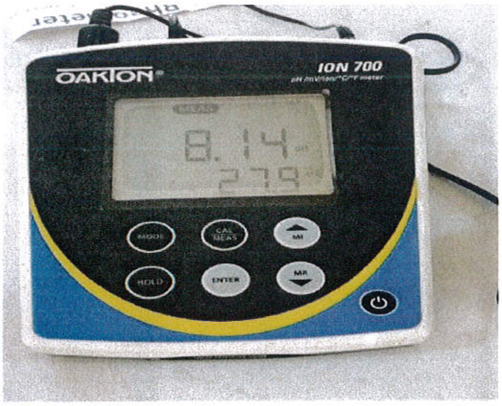


Plate 3.5: pH meter

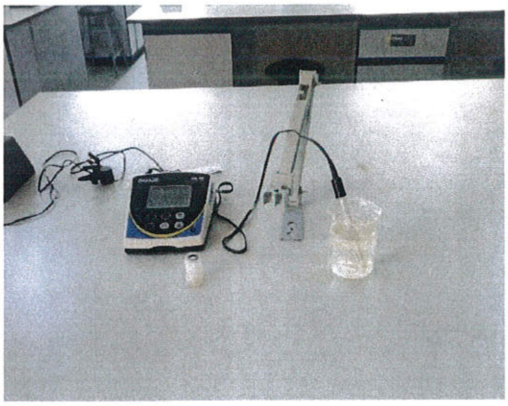


Plate 3.5.1: The set up of the procedure

3.4.4 Conductivity

Conductivity is a measure of how well a material conducts electricity. This was done using a Jenway conductivity meter (4510 model). The probe was dipped into the container of the samples until a stable reading was obtained and the value recorded.

Plate 3.6: Jenway conductivity meter

3.4.5 Total dissolved solids (TDS)

Total dissolved solids (TDS) is a measure of dissolved combined content of all inorganic and organic substances contained in a liquid, in molecular, ionized or granular suspended form.

TDS can be determined by Gravimetric Method

a. Obtain 250ml of the sample and filtered using a filter paper, and then 10ml of the filtrate was collected and measured into a pre-weighed evaporating dish.
b. Following the procedure for the determination of total solids above, the total dissolved solids content of the water was calculated.

Total dissolved solids (mg/l) = $$\frac{퐖_2 − 퐖_1 □□ □× □□□□}{□ □□퐬퐬□□퐟□□ 퐞□퐦}$$ (3.1)

W_1 = initial weight of evaporating dish

W_2 = Final weight of the dish (evaporating dish + residue).

Plate 3.7: TDS determination

3.4.6 Total suspended solid (TSS)

a. Measuring 50 ml each of the samples which was sieved by using a filter paper and dried in an oven at 103°C.

b. The dried sample was cooled in a desiccator and reweighed.

c. The process was repeated until the weight became constant

$$\text{Total Suspended Solid (TSS)} = \frac{W_2 - W_1 \times 10^6}{V} \quad (3.2)$$

Where

W_1= initial weight of the sample

W_2 = Final weight of the sample (dried sample)

V= Volume

3.4.7 Alkalinity

It is composed primarily of carbonate and bicarbonate, alkalinity acts as a stabilizer for pH.

a. The sample bottle was filled with the water sample, a 5ml cuvette was filled with the water sample and the cuvette was inserted into a UV spectrophotometer.

b. The meter was turned on, the button was press to "Blank" and the cuvette was removed.

c. A clean cuvette was filled to the 5ml line with the water sample. 5 drops of alkalinity reagent were added.

d. The cuvette was capped, inverted 3 times to mix and inserted into the photometer. The button was pressed to go to Alk" alkalinity.

e. The readings were recorded in mg/l and the cuvette was removed

3.4.8 Total bacteria count and coliform count

The total coliform bacteria test is a primary indicator of "potability", suitability for consumption, of drinking water. It measures the concentration of total coliform bacteria associated with possible presence of disease-causing organisms. The samples for bacteriological analysis were subjected to total bacteria count and coliform count. Nutrient agar medium was used to obtain plate count of living bacteria (viable cell count).

Procedure

a. The procedure involved mixing 1ml of water sample with liquefied agar at 40°C in a Petri dish. The agar sets to a jelly, thus fixing the bacteria cell in position.

b. The plate was then incubated under appropriate condition (24 hours at 37ºC for bacteria organism from animal or man).

c. At the end of the incubation, the individual bacteria would have produced colonies visible to the naked eyes and the number of colonies was assumed to be a function of the viable cells in the original sample.

d. Coliform count was achieved using a lactose medium inoculated with serial dilution of the sample.

e. The appearance of acid and gas after 24 hours at 37°C was taken as positive indication of the presence of coliform bacteria; results were expressed as number of colonies per 100ml.

3.4.9 Dissolved oxygen

The dissolved oxygen (DO) is oxygen that is dissolved in water. Dissolved oxygen analysis measures the amount of gaseous oxygen (O2) dissolved in an aqueous solution.

Determination of dissolved oxygen was done using Winkler's method:

a. Excess Manganese (II) salt, iodide (I-) and hydroxide (OH-) ions were added to the samples causing a white precipitate of $Mn(OH)_2$ to form.
b. This precipitate was th0en oxidized by the dissolved oxygen in the sample into a brown manganese precipitate. Then sulphuric acid is added to acidify the solution.
c. The brown precipitate then converts the iodide ion (I^-) to iodine. 300ml BOD bottles were filled with the samples respectively, 2mL of manganese sulphate and 2ml of alkali-iodide-azide solution added by inserting a pipette just below the surface of the liquid.
d. The bottles were stopped to avoid the introduction of air and were mixed by inverting several times.
e. The bottles were left to stand for a few minutes. The presence of oxygen is indicated by the formation of a brownish –orange precipitate. 2ml of H_2SO_4 was added to the samples.
f. It was mixed again by inverting to dissolve the precipitate. 201ml of the sample was then measured into a clean 250ml conical flask and titrated against sodium thiosulphate solution (Na_2S_2O $_3.5H$ $_2O$) using the starch indicator until the solution turned colorless.

Calculation

$$\text{DO (mg/l)} = \frac{\square 6 \square\square \times \text{퍼} \times \square}{\square_2 / \square_1\ \square\square\square - \square\square\square} \qquad (3.3)$$

Where

M = Molarity of thiosulphate used.

V = volume of thiosulphate used for titration

V_1 =Volume of bottle with stopper

V_2 = Volume of aliquot taken for titration.

Plate 3.8: Dissolve Oxygen Meter

3.4.10 Biochemical oxygen demand (BOD)

The biochemical oxygen demand determination is a chemical procedure for determining the amount of dissolved oxygen needed by aerobic organisms in a water body to break the organic materials present in the given water sample at certain temperature over a specific period of time.

Apparatus

a. BOD bottle
b. Beaker (250 ml)
c. Measuring cylinder
d. Stirrer

Procedure

a. Fill the samples to overflow, in an airtight bottle of the specified size and incubate it at the specified temperature for 5days.
b. Dissolved oxygen (DO) is measured initially and after incubation and the BOD is computed from the difference between initial and final (DO). Because the initial (DO) is determined shortly after the dilutions is added, all oxygen uptake occurring after this measurement is included in the BOD measurement.
c. 1ml of $MgSO_4$, $CaCl_2$, phosphate buffer, $FeCl_3$ was added to 1L of water.
d. The solution was then shaken thoroughly to saturate the dissolved oxygen.

e. This solution was used to dilute samples. It should be noted that when effluent from a biological treatment process is used, inhibition of nitrification is recommended. This is done using a nitrification inhibitor.

f. Sample dilution is necessary before incubation to ensure that all the dissolved oxygen is not used during incubation.

g. One hundred millimeters (100mL) of the samples were measured into different 1L flask and made up to 1L mark with the dilution water previously prepared.

h. The dilution sample solution was then poured into BOD bottles and subsequently incubated at 20°C in the dark for 5 days

    1. **Determination of initial dissolved oxygen:** 300ml BOD bottles were filled with the diluted samples previously prepared and the initial dissolved oxygen (DO) is determined using the Winkler's method
    2. **Determination of Final Dissolved Oxygen:** After incubation for 5days, the final dissolved oxygen (DO) was determined using the same procedure above

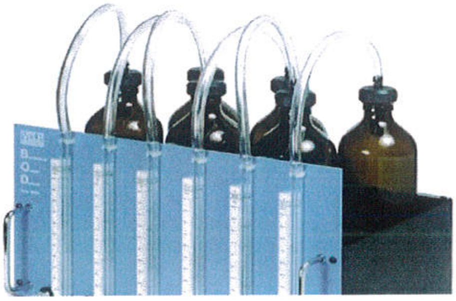


Plate 3.9: BOD Set up apparatus

$$\mathrm{BOD\ (mg/l)} = \frac{\text{퍗폑}_1 - \text{퍗폑}_0}{\text{팹}} \qquad (3.4)$$

Where

DO_0 = initial dissolved oxygen (immediately after preparation)

DO_1 = final dissolved oxygen (after 5days of incubation)

B = Fraction of sample used.

3.5. Main Investigations

3.5.1 Chlorine residual test (Jar Test)

"Jar Test" was been developed to ensure a correct chlorination. This procedure can be performed in the field, and if flexible enough to meet all the different situations.

Material needed

To conduct a jar test, the following material is needed:

a) 1 small container of known volume (i.e. 1 liter)
b) 4 (5) big containers of known volume (i.e. 10 liters)
c) 1 syringe 5 or 10 ml
d) 1 measuring device for approximately 10 g (i.e. a tea spoon, or a matchbox)
e) 1 free chlorine comparator

Procedure

A solution (slug) of concentrate chlorine has to be prepared prior the chlorination.

a) Fill the entire beaker with the water to be chlorinated and label appropriately.
b) Add 1 tablet pillow of your chlorination product to the smallest beaker, and mix until the chlorine powder is completely dissolved.
c) Fill the syringe with the concentrate solution
d) Add the concentrate solution to the other beakers in increasing quantities

   i.e.

   1st container: 1.2 ml
   2nd container:1.5 ml
   3rd container: 1.8 ml
   4th container: 2.0 ml
   5th container: 2.5 ml
e) Mix the contents and wait at least 30 minutes
f) Measure the residual chlorine of each container.
g) Choose the container that shows residual chlorine between 0.2 and 0.5mg/l. This is the required concentration of chlorine for the disinfection of the water.

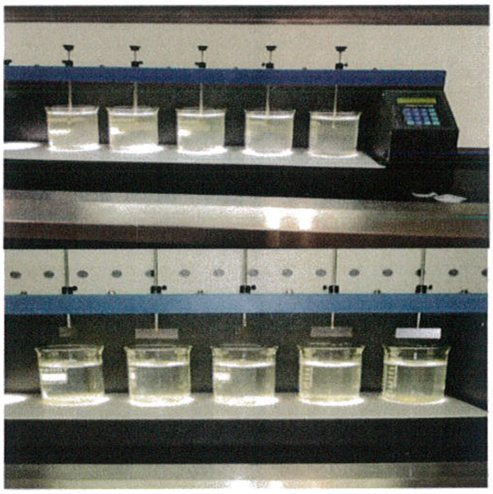


Plate 3.10: Jar test apparatus

3.5.2 Chlorine dosing

To prepare the chlorine doses for chlorinating the samples, condensed sodium hypochlorite (15 g/l) was initially diluted to the desired level and then a defined amount of the resulted solution was used.

a. 1ml of condensed sodium hypochlorite which contains about 15g of free chlorine was dosed into a 100ml of deionized water to achieve 150mg/l of free chlorine concentration.
b. The diluted solutions of 150mg/l concentration were prepared freshly every day when the experiments were carried out.
c. The next step was to calculate the volume of diluted chlorine solution, which was required to add to the water samples.
d. The chlorine concentrations specified for testing the water samples ranged from 0.2 to 0.5mg/l of Cl_2

3.5.3 DPD free chlorine comparator

The most common test used to measure the residual chlorine levels is the DPD (diethyl paraphenylene diamine) indicator test, using a comparator. With this test, a tablet reagent is being added to a sample of water, colouring it red. The strength of colour is measured against standard colours on a chart used to determine the chlorine concentration.

The stronger the colour, the higher the concentration of chlorine in the water. Several similar kits for analyzing the chlorine residual in water are available commercially. The kits are small and portable.

Plate 3.11: Comparator with DPD tablet (UNICEF,2005)

Procedure

a) Pour the water to be tested in the comparator
b) Add 1 tablet DPD No. 1
c) Shake well until the tablet is completely dissolved
d) Compare the color of the water against the standard colors in the kit in full light on a white background and note the result Ideal residual should be 0.2 – 0.5mg/l.

3.5.4 Bulk chlorine decay determination

This study aims at design a chlorination system for Federal University Oye-Ekiti, Ikole campus. It will entail water quality assessment of available water sources obtainable in the campus which includes surface and ground water source; bulk decay experiment on chlorination to determine the decay rate of chlorine in the different water sources.

The determination of bulk chlorine decay was carried out using the following procedure:

All glassware was treated to ensure that any chlorine demand exerted by the glass had been satisfied.

a) A 250ml beaker was filled with 200ml of the water sample, and then the water was thoroughly mixed to ensure homogeneity for approximately 1 minute.
b) The water samples were dosed with chlorine by using sodium hypochlorite solution (150 mg/l) after dilution to achieve various initial chlorine concentrations.

- **c)** The sample water was then decanted into 100ml glass amber bottles that were sealed with plastic stoppers, ensuring only limited amount of air remained inside.
- **d)** All samples were stored in an incubator set to ambient temperature of the water sample during the investigations, which was about 20°C.
- **e)** The chlorine concentrations within the bottle was then determined using the N,N-diethyl-phenylenediamine (DPD) colorimetric method. The starting time and initial chlorine concentration were recorded.

The measurements of free chlorine concentrations were performed at defined intervals and lasted until free chlorine concentrations reached 0.2 -0.5mg/l.

3.5.5 Chlorine demand determination

Procedure

1. Determine Actual Bleach Concentration
   - **a)** For 8.25% bleach put 1 ml in 100ml of distilled water
   - **b)** Add 1 ml of solution in "a" in 100ml of distilled water.
   - **c)** Run Free chlorine residual of solution in "b".
2. Ammonia concentrations of the water samples were determined.
3. The theoretical demand of the water samples to be tested was estimated.
4. Prepare five 100ml of the water samples.
5. After adding the appropriate amount of chlorine to each test beaker, allow 30 minutes of reaction time for the chlorine.
6. Plot the free chlorine residual versus the amount of chlorine added and estimate the breakpoint which is the point where the chlorine demand has been satisfied and free chlorine begins to increase proportionally to the amount of chlorine added.

3.6 Chlorination System

A demonstration chlorination system installation is shown in Figure 3.2 below. Disinfection contact time zone is usually measured along the service main. Initial chlorine concentration □[illegible]□is determined at the chlorine injection point and chlorine is injected using chlorine injection pump. CT disinfection is determined along the main contact time zone and not at the point of use. Water samples for residual chlorine determination is obtained at the point of first use.

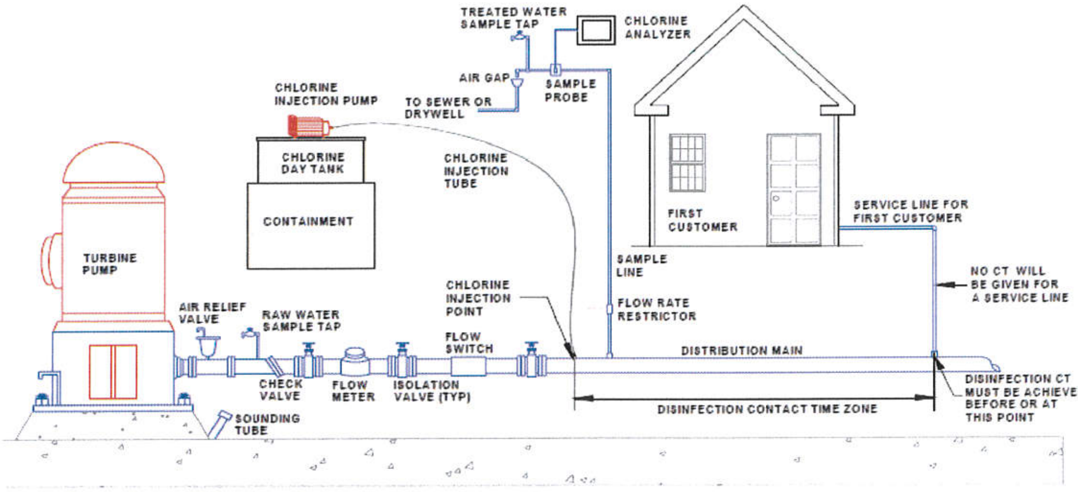


Figure 3.3: Typical chlorination system installation

3.6.1 Contact time and CT achieved

For a plugged flow through a piped network contact time for flow through a conduit pipe network was determined using Equation (3.2)

$$\text{[illegible]} = \frac{\text{[illegible]}\,(\;^{3})*6\,\text{[illegible]}}{\text{[illegible]}\;^{3}} \qquad (3.5)$$

For a bulk chlorine experiment, the contact time measures the time from when the initial chlorine concentration was added to the time the residual concentration is measured. Useful CT disinfection computation for this purpose is shown in equation (2.2).

3.6.2 CT disinfection determination

This section comprehensively reviews the work of Rush, (2002) on CT disinfection. Procedural steps in the use of tables and charts are as follows:

Step 1: ***Determining the required CT (CT*** $_{\textit{required}}$***)***

This determines CT required based on recommended value. These values can be obtained from EPA, 1999 manual. Example of such CT table is shown in Table 3.1

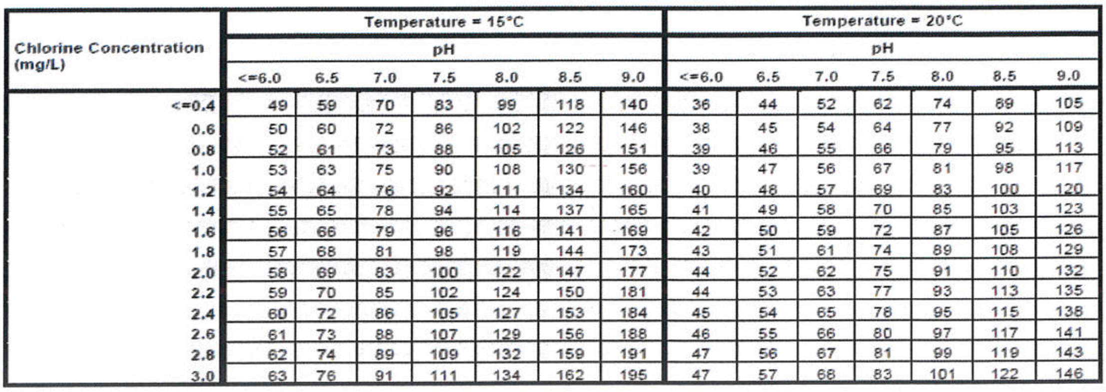
Step 2: ***Determining the actual CT (CT*** $_{\textit{achieved}}$***)***

The estimation of the actual $CT_{achieved}$ considering only pipe flow is computed using Equation (3.5). In this study it was determined as the time required for the initial chlorine concentration to reach a residual value of between 0.2 to 0.5 mg/l.

Step 3: ***Comparing CT Values***

If $CT_{acheived} \geq CT_{required}$, then you will have met your disinfection requirement. If not, you must take the appropriate actions to ensure CT Disinfection requirements are met.

Table 3.1: CT values for 3-Log inactivation of *giardia* cysts by free



Chlorine Concentration (mg/L)	Temperature = 15°C							Temperature = 20°C						
	pH							pH						
	<=6.0	6.5	7.0	7.5	8.0	8.5	9.0	<=6.0	6.5	7.0	7.5	8.0	8.5	9.0
<=0.4	49	59	70	83	99	118	140	36	44	52	62	74	89	105
0.6	50	60	72	86	102	122	146	38	45	54	64	77	92	109
0.8	52	61	73	88	105	126	151	39	46	55	66	79	95	113
1.0	53	63	75	90	108	130	156	39	47	56	67	81	98	117
1.2	54	64	76	92	111	134	160	40	48	57	69	83	100	120
1.4	55	65	78	94	114	137	165	41	49	58	70	85	103	123
1.6	56	66	79	96	116	141	169	42	50	59	72	87	105	126
1.8	57	68	81	98	119	144	173	43	51	61	74	89	108	129
2.0	58	69	83	100	122	147	177	44	52	62	75	91	110	132
2.2	59	70	85	102	124	150	181	44	53	63	77	93	113	135
2.4	60	72	86	105	127	153	184	45	54	65	78	95	115	138
2.6	61	73	88	107	129	156	188	46	55	66	80	97	117	141
2.8	62	74	89	109	132	159	191	47	56	67	81	99	119	143
3.0	63	76	91	111	134	162	195	47	57	68	83	101	122	146

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

The results of the physio-chemical parameters of different samples of stream and borehole water analyzed are as shown in Table 4.1. In this study, the NSDWQ is established for important physio-chemical parameters such as pH, alkalinity, conductivity, turbidity, total solids, total coliform and bacteria count, dissolved oxygen, biochemical oxygen demand and residual chlorine. All the water samples taken from sources were tested for physical, chemical and microbiological qualities of the water sources. The parameters in Table 4.1 affect chlorine decay in a drinking water. For the purpose of this discussion, the various parameters are grouped into: physical, chemical, and biological.

4.2 Physical, Chemical and Biological Test

From the results in Table 4.2 and Figure 4.2, temperature affects chlorine decay more than any other physical parameter, and therefore is of prime importance. Temperature, color, odor is below the WHO/NSDWQ standards. From the water samples analyzed for appearance, only one water sample source was not clear and that was sample A which is a stream. Water sourced from borehole met the entire requirement.

Table 4.2, 4.3, 4.4 and Figures4.2, 4.3 and 4.4 shows the comparison of the result with the NSDWQ standard for physical, chemical and microbiological parameters respectively. The results indicate that the samples analyzed from borehole water are safe for human consumption and for other domestic purposes while the samples analyzed from stream water are not safe for human consumption.

4.2.1 Discussion on parameters related to chlorine decay

Turbidity: For test on turbidity, it varied between the borehole and stream water sources. The highest turbidity was recorded in the stream surface water source and the lowest turbidity was recorded in the borehole water source. Only borehole sample was within the limits prescribed by NSDWQ standards (5NTU). From the result found, the water from the stream water source was slightly more turbid than the borehole water source. This slight turbidity indicates that there may be presence of inorganic particulate matter and nonsoluble metal oxides. The consumption of high turbid water may cause a health risk, as excessive turbidity can protect pathogenic microorganisms from effects of disinfectants (Singh et al.2013; Tiwari and Singh 2014). 12.5% of the samples also didn't meet the NSDWQ requirement while the remaining 87.5% met the recommended value of WHO that is 5 NTU in the rural.

RESULTS OF ANALYSIS

Table 4.1: Physio-chemical analysis for stream and borehole water samples

S/N	Parameters	Sample A (Stream)	Sample B (Borehole)
1	Ph	8.42	6.98
2	Temperature (^{0}C)	27.70	28.60
3	Conductivity (μS/cm)	95.60	30.18
4	Colour (TCU)	8	5
5	Salinity (mg/l)	120.45	79.50
6	Turbidity (NTU)	9.40	0.26
7	Total Solid TS (mg/l)	240.00	125.00
8	Alkalinity (mg/l)	1.54	0.75
9	Total Dissolved Solid TDS (mg/l)	18.00	90.00
10	Total Suspended Solid TSS (mg/l)	230.00	15.00
11	Total Bacteria count (cfu/ml)	1.0×10^2	0.00
12	Total Coliform count (MPN/100ml)	1.47	0.00
s13	Dissolved Oxygen DO (mg/l)	2.60	3.45
14	Biochemical Oxygen Demand BOD (mg/l)	2.15	0.20
15	(Residual chlorine mg/l)	<0.001	0.24

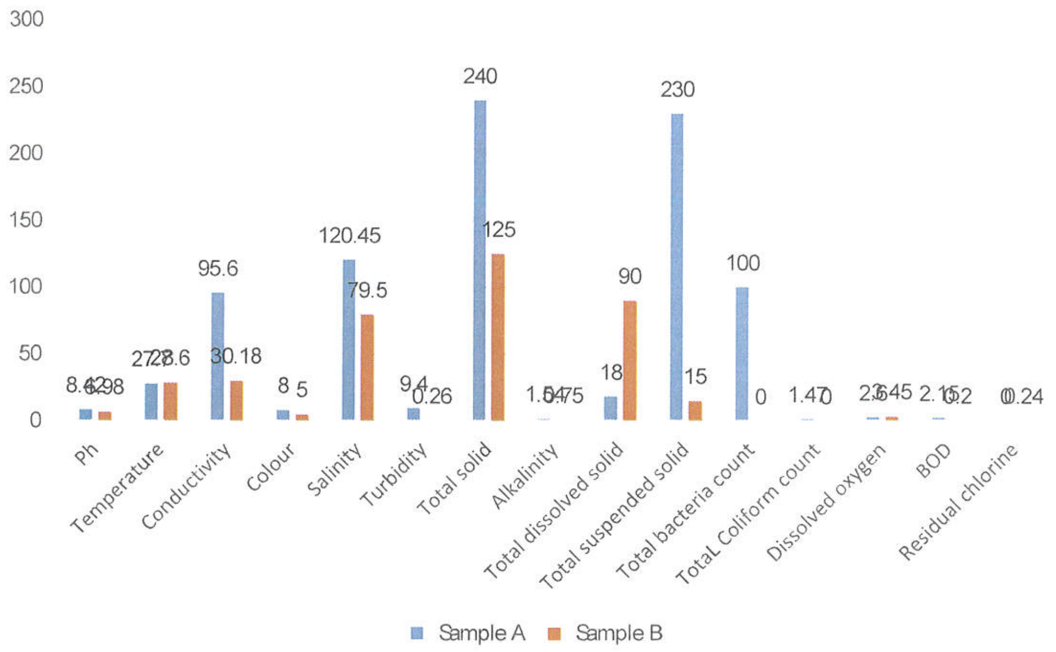


Figure 4.1: Spatial variation in stream and borehole water sources

Temperature: The temperature of the two samples is more than 20^0C, Sample B temperature is higher than that of sample A probably because it was obtained from underground source. The both temperatures looks high but are both within the specified limits of NSDWQ specification. Temperature is a very important control parameter for the determination of chlorine demand.

Color: Sample A (8 TCU) is higher than that of sample B (5 TCU) due to the presence of colored organic matter such as humic substances, metals such as iron and manganese or by substances of vegetable origin such as algae and weeds etc. However, Colour should be less than 15.0 units of color, The color in all the Samples were below WHO Standards, therefore, they are within the permissible limit

Salinity: is the amount of salt dissolved in a body of water. the presence of salt is high in sample A and lower in sample B. Salinity is also concerned with total dissolved solids TDS and electrical conductivity EC.

Table 4.2: Physical Parameters

S/N	**Parameter**	**A**	**B**	**NSDWQ standards**
1	Temp (^{0}c)	27.70	28.60	22-30
2	Appearance	Brownish	Clear	CLEAR/COLOURLESS
3	Colour(Hazen)	8.00	5.00	15 TCU
4	Taste	Present	None	Unobjectionable
5	Odour (Ton)	None	None	Unobjectionable

Table 4.3: Chemical Parameter

S/N	Parameter	A	B	LIMITS
1	Ph	8.42	6.98	6.5-8.5
2	Conductivity	95.60	30.18	1000
3	Turbidity	9.40	0.26	5NTU
4	Total Solid mg/l	240.00	125.00	500
5	Residual Chlorine	<0.001	0.24	0.2-0.5
6	Total Alkalinity	1.54	0.75	100
7	Total Dissolved Solid TDS (mg/l)	18.00	90.00	500
8	Total Suspended Solid TSS (mg/l)	230.00	15.00	500
9	Dissolved Oxygen DO (mg/l)	2.60	3.45	5
10	Biological Oxygen Demand	2.50	0.75	3-5

Table 4.4: Micro-Biological parameters

S/N	Parameter	A	B	LIMITS
1	Total Bacteria Count (cfu/ml)	1.0×10^2	0.00	10^3
2	Total Coliform Count (MPN/100ml)	1.47	0.00	0.00

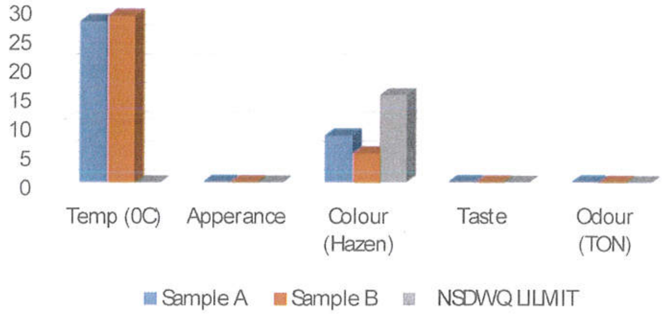


Figure 4.2: Chart comparing the Physical parameters with the Limit

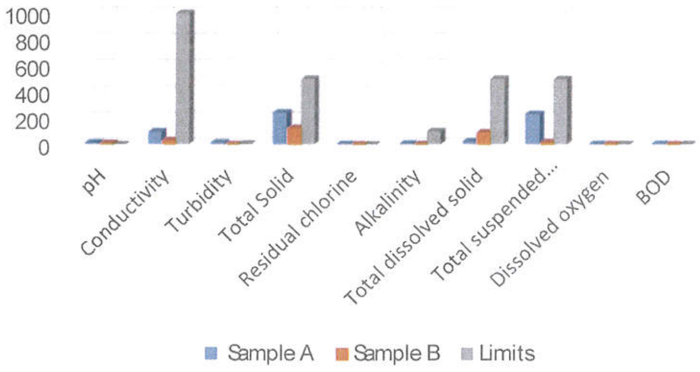


Figure 4.3: Chart comparing the Chemical parameters with the Limit

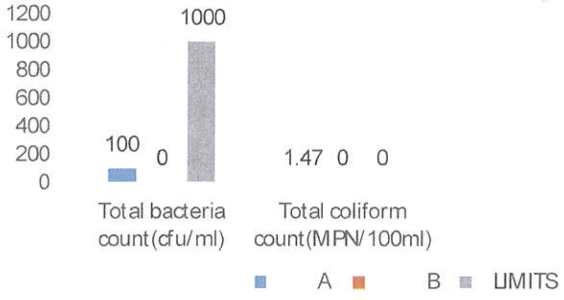


Figure 4.4: Chart comparing the Micro-Biological parameters with the Limit

pH: For pH, it is an important parameter which determines the suitability of water for various purposes. The pH value for all the water samples was within the range of NSDWQ standard of (6.5-8.5) on average the pH values obtained were 6.98 and 8.42. The least Ph value 6.98 was recorded in the borehole water sample, while the maximum value of 8.42 was recorded in the stream water respectively. From the above result, the sample B analyzed were slightly acidic. pH was positively correlated with electrical conductance and total alkalinity (Guptaa 2009). From Table 4.1, pH in sample B (borehole) is lower than that of sample A (stream) due to the low alkalinity. High pH levels also depress the effectiveness of disinfection by chlorination, thereby requiring the use of additional chlorine or longer contact time.

Alkalinity: Chlorine in very small doses and minimal contact time can easily kill even the most heinous (extremely stubborn) of bacteria. Recommended standards are specified at 100 mg/l, the water samples analysed were within the recommended standards for drinking water. The alkalinity was present in the range 1.54 and 0.75 mg\l which was within the limits of WHO and NSDWQ standards. The alkalinity level of all the Samples were below WHO Standards, therefore, they are within the permissible limit. Higher concentration of alkalinity in the water samples can lead to corrosion of metals.

Conductivity: This quality falls within the permissible value of W.H.O (1000 ohms/cm), on average, the value obtained from the analyzed water samples was 62.89 ohms/cm. Sample A conducts more electricity than sample B (i.e. it is lower in conductivity)

Residual Chlorine: Residual Chlorine of 0.24 mg/l was detected in the water sample B from borehole source. This is slightly above the minimal recommended value of 0.2 mg/l expected to be observed in a treated water sample. Residual chlorine is useful for the disinfection of common pathogenic organisms like bacteria, and virus. This can also be the reason for the low coliform and bacteria count in sample B. For sample A, there is no residual concentration of chlorine in it and therefore is prone to contamination.

Total solids (TS): The value for both water samples A and B ranged between 240.0mg\l and 125.0 mg/l respectively. The value for both water samples are within the WHO and NSDWQ permissible limits.

Total Dissolved Solids (TDS) is indicative of the salinity behavior of water. TDS in all the water samples analyzed were within the recommended standards for drinking water. TDS in drinking water has also been associated with natural source, sewage, industrial wastewater, urban run-off and chemical used in water treatment process.

Total suspended solid (TSS) is the turbidity caused due to silt and organic matter. In the study area, maximum TSS concentrations were found in the stream water sample and minimum TSS concentrations were found in the borehole groundwater source 230.0 and 15.0of mg/l respectively. Minimum variation was observed between the stream water and borehole water source. No guideline value is set for TSS because of is less health concern.

Dissolved Oxygen (DO): is an important parameter which is essential to the metabolism of all aquatic organisms that possess aerobic respiration. Presence of DO in water may be due to direct diffusion from air and photosynthesis activity of autotrophs. Oxygen can be rapidly removed from the waters by discharge of oxygen demanding wastes. The values of DO obtained in this study are within the recommended standards. There are no limiting values given for dissolved oxygen in drinking water by WHO and NSDWQ.

Biochemical Oxygen Demand (BOD): The Biochemical oxygen demand BOD is a test for measuring the amount of biodegradable organic material present in a sample of water. BOD is the parameter used to assess the pollution of surface water and ground water. The values obtained for BOD in this study are within the recommended standards for all the water samples analyzed.

Total Bacteria count (cfu/ml): The guideline for total bacteria count in drinking water should be none detectable per 100ml. bacteria is detected in sample A while it is none detectable in sample B which is within permissible limits.

Total coliform count (MPN/100ml): include bacteria that are found in the soil, in water that has been influenced by surface waters and in human or animal waste. It also indicates fecal contamination. The most commonly measured indicators of water quality are the coliform organisms. The guideline for total coliform in drinking water should be none detectable per 100ml. therefore sample A exceeds the permissible limit for drinking water while sample B are within permissible limits.

4.3 Chlorine Jar Test

This examines bulk chlorine decay in a de-chlorinated Jar bottle sample. The Jar test measure bulk chlorine decay in a Jar bottle. An initial chlorine dose of 1.2 to 3 mg/l was added to six (6) different bottles to determine the required contact time for to achieve a residual concentration of 0.2 mg/l to 0.5 mg/l. This is the recommended residual range required in drinking water in other to avoid negative consequences of over dose. CT disinfection shows the required disinfection which must be achieved to satisfy disinfection requirement for the different pathogenic organisms like bacteria and virus.

JARS 5 and 6 are the only jars that is able to disinfect the water in the shortest possible time of 45 mins at a concentration of 1.5 and 1.2 mg/l respectively.

Table 4.5 shows the: decay rates, contact time, and CT disinfection achieved. From Table 4.5, there is a significant change in decay rate at an initial concentration of 2.0mg/l. The decay rates after this point (i.e. for initial concentration of 2 to 3 mg/l) show a slower rate of decay as evident in the large contact time utilized. The decay rates before this point (i.e. initial concentration of 1.2 to 1.8 mg/l) indicate a faster rate of decay. The reason for this is unknown. This varying decay rates also affected the CT disinfection values as higher values are obtained for concentration values of 2 to 3 mg/l.

Table 4.5: Jar test data for sample A

JAR #	**Initial Chlorine Concentration (mg/l)**	**Residual Chlorine (Mg/l)**	**Contact time (minutes)**	**Chlorine Decay Rate (mg/l/mins)**	**CT Achieved (mgminsL^{-1})**
1	3.0	0.2 – 0.5	360	0.0078	180
2	2.5	0.2 – 0.5	360	0.0064	180
3	2.0	0.2 – 0.5	240	0.0075	120
4	1.8	0.2 – 0.5	60	0.0267	30
5	1.5	0.2 – 0.5	45	0.0289	22.5
6	1.2	0.2 – 0.5	45	0.0222	22.5

Table 4.6: Supernatant Turbidity for sample A

JAR #	Unfiltered Supernatant Turbidity (NTU)	Concentration (mg/l)	Filtered Supernatant (NTU)	Concentration (mg/l)
1	9.50	3.0	3.56	3.0
2	8.42	2.5	2.45	2.5
3	6.20	2.0	2.32	2.0
4	4.90	1.8	1.87	1.8
5	6.52	1.5	2.36	1.5
6	8.05	1.2	4.17	1.2

Table 4.6 shows the supernatant turbidity for the six different water samples. The compares the chlorine concentration added to the observed turbidity in the water sample. This was done for both the filtered and the unfiltered water samples. Lower turbidity values were obtained for the filtered water sample which is expected.

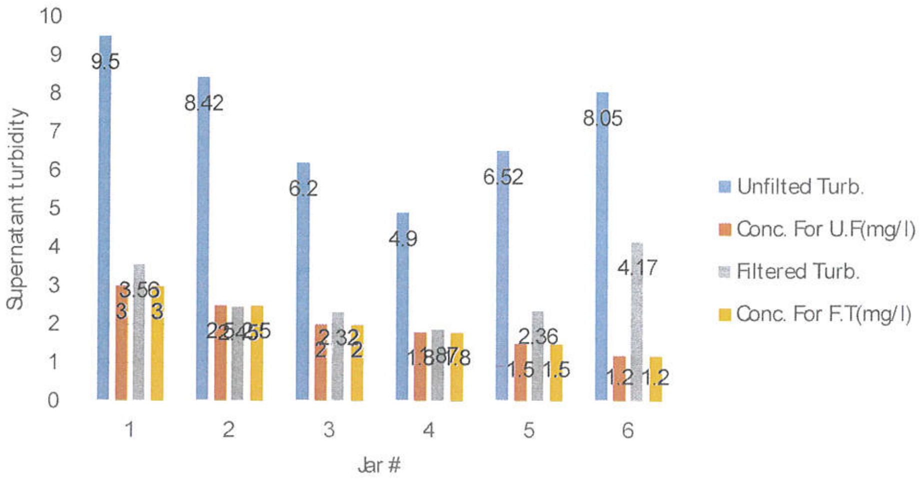


Figure 4.5: Chart for sample A jar test showing filtered and non-filtered analysis

From Table 4.7, the decay rate is faster at lower initial concentration. Therefore the 1.2mg/l initial concentration has the fastest decay rate, while the 3.0mg/l shows lowest decay rate. Chlorine contact time in water is directly proportional to the initial concentration amount of chlorine in water. Higher Ct values are achieved for higher initial concentration of chlorine dose added to water.

From the experiment which is aimed at selecting the container that shows residual chlorine between 0.2 and 0.5mg/l in the shortest possible time. This is the required concentration of chlorine for the disinfection of the water.

JAR 6 is the only jar that is able to disinfect the water in the shortest possible time of 10 minutes at a concentration of 1.2 mg/l.

Table 4.7: Jar Test Data for sample B

JAR #	**mg/l**	**Requirements (Mg/l)**	**Contact time exposure (Minutes)**	**Chlorine Decay Rate (mg/l/mins)**	**CT Achieved (mgminsL^{-1})**
1	3.0	0.2 – 0.5	45	0.062	22.5
2	2.5	0.2 – 0.5	30	0.076	15
3	2.0	0.2 – 0.5	20	0.090	10
4	1.8	0.2 – 0.5	15	0.0267	7.5
5	1.5	0.2 – 0.5	12	0.11	6.0
6	1.2	0.2 – 0.5	10	0.10	5.0

Table 4.8: Supernatant Turbidity for sample B

JAR #	Supernatant Turbidity Unfiltered	Concentration (mg/l)	Filtered Supernatant	Concentration (mg/l)
1	1.38	3.0	0.43	3.0
2	1.02	2.5	0.40	2.5
3	1.26	2.0	2.0	2.0
4	0.47	1.8	1.8	1.8
5	0.50	1.5	1.5	1.5
6	1.68	1.2	0.57	1.2

Unfiltered water samples from the water source B (Borehole) were distributed into six 6 jars, and their respective turbidity values ranging between 1.68 to 0.47 for the six jars. The values are 1.38, 1.02, 1.26, 0.47, 0.50 and 1.68 NTU'S for jars 1,2,3,4,5, and 6 respectively.

The six samples from the borehole source were not turbid. They fall within WHO standard which is 6 NTU and NSDWQ standard which is 5 NTU. When the samples were filtered, the values were further reduced to the range of 0.40 to 2.00 NTU which fall within the permissible limits.

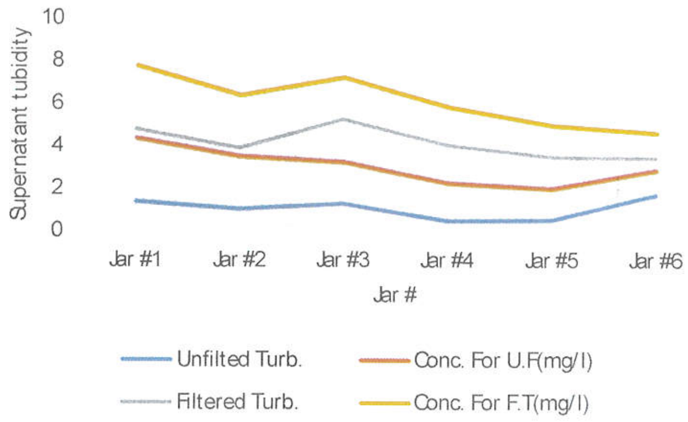


Fig 4.6: Chart of Jar test for sample B of supernatant Turbidity

4.4 Chlorine Decay Test

This indicates how the initial chlorine concentration decays in water. The free chlorine concentration is measured at regular time interval to determine the decay rate. E.g. for sample A, at time interval of 360 minutes there is no free chlorine residual in the sample. Chlorine decay means the decrease (or reduction) in the concentration of chlorine in drinking water as it passes from the water treatment plant through to the end of the distribution system.

According to the WHO drinking water standard state that 2-5 mg/l chlorine should be added to water in order to gain a satisfactory disinfection and residual concentration. WHO stipulates a residual amount of chlorine of 0.5**mg/l** after at least 30 minutes of contact time and at a pH value of 8 or less (EPA, 2011), and also a residual concentration of between 0.5 to 0.2 mg/l within the distribution line. If the dosing rate of chlorine is below guidelines, there may be insufficient residual later, resulting in bacterial regrowth if the water is contaminated in the storage or distribution system.

Table 4.9: Chlorine decay test (sample A)

Contact	**Initial Dosing (mg/l)**					
Time (mins)	**3.0**	**2.5**	**2.0**	**1.8**	**1.5**	**1.2**
0	3.0	2.5	2.0	1.8	1.5	1.2
5	2.6	2.0	1.8	1.4	1.2	0.8
15	2.2	1.9	1.6	1.2	1.0	0.9
30	2.0	1.8	1.5	1.0	0.8	0.6
45	1.7	1.5	1.2	0.7	0.5	0.6
60	1.4	1.4	1.0	0.5	0.4	0.3
90	1.2	1.4	0.8	0.4	0.3	0.3
120	1.2	1.3	0.7	0.4	0.3	0.3
240	1.0	0.8	0.5	0.3	0.2	0.2
360	0.5	0.5	0.4	0.2	ND	ND
480	0.4	0.2	0.1	ND	ND	ND

Note: ND means not-detectable (the chlorine has already been used up leaving no residual at a particular time) **i.e.** at 6 hours the dosing of 1.5mg/l is not detectable.

From this thesis, we are critically looking at the decay that occurs around the 30 minutes contact time interval, even though the decay test lasted for 480 minutes (8 hours). But at 30 minutes, there should have around 0.5 mg/l of free chlorine present in the water sample. At 30 minutes, only 1.5 and 1.2 mg/l initial concentration are close to this requirement. Therefore, these two provides the best initial values and is recommended for treatment purpose. But they show a residual chlorine of 0.8mg/l and 0.6 mg/l after 30 minutes contact time as specified by water safety system.

For time 45 minutes, initial dosing of 1.5mg/l already decayed to 0.5mg/l. Note that, at this time an initial lower dosing of 1.2 mg/l is slightly higher than the 1.5mg/`l dosing. Thus, it is important to know that the smaller the initial dosing does not guarantee faster chlorine decay. We then see a constant decay from there. Usually, there is usually an initial period of several hours during which the decay rate is much higher than the longer-term rate (characterized by the rate coefficient *k)*.

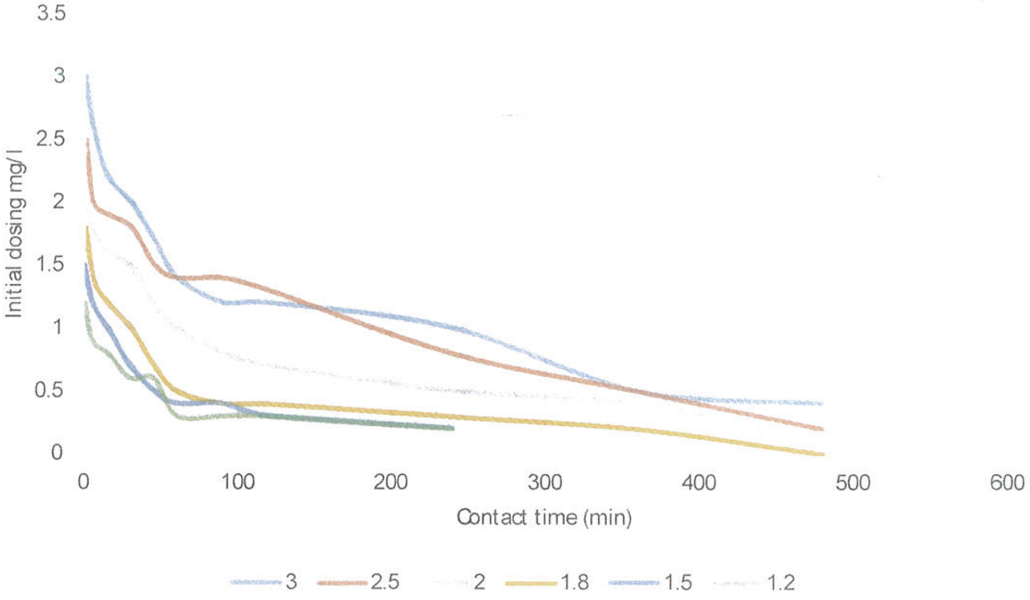


Figure 4.7: Chart of chlorine decay test for sample A

At time 360 minutes (6 hours), all the initial dosing from 3.0mg/l to 1.2 mg/l all shows the maximum residual chlorine of between 0.5mg/l and 0.2mg/l. At this time, permissible chlorine requirements limit by the NSWQW have been satisfied. Of much importance, at 360 minutes, the chlorine has already been used up leaving no residual at a particular time. Chlorine is not detectable. Hence from this result **1.5mg/l** is the best dosage for sample A (stream water) because it gives the shortest possible time to kill the germs present in the water (contact time) achieved at 45 min.

According to the WHO drinking water standard state that 2-3 mg/l chlorine should be added to water in order to gain a satisfactory disinfection and residual concentration. The maximum amount of chlorine one can use is 5mg/l for drinking water purposes. Expected residual concentration after at least 30 minutes of contact time and at a pH value of 8 or less is 0.5 mg/l. If the dosing rate of chlorine is below guidelines, there may be insufficient residual later, resulting in bacterial regrowth if the water is contaminated in the storage or distribution system.

Chlorine decay is still frequently expressed as a simple exponential reduction of chlorine concentration in water with time. For this study a first order model is adopted and present thus:

$$C(t) = C_0 \exp(-kt) \quad 4.1$$

Where,

$C(t)$ is the chlorine concentration at time t,

C_0 is the initial concentration at time t=o in mg/l

k is the first order decay constant in (h^{-1})

t is the contact time

K values can be obtained from Table 4.5 and 4.7 respectively. Apply to equation 4.1, the decay model for the initial dose of 1.5 (Table 4.9) is shown below

$$C(t) = 1.5 \exp(-0.0289t) \quad 4.2$$

With this distribution, residual concentration over a period of days can be determined

Table 4.10: Chlorine decay test for sample B

Contact Time (mins)	**Initial Dosing (mg/l)**					
	3.0	**2.5**	**2.0**	**1.8**	**1.5**	**1.2**
0	3.0	2.5	2.0	1.8	1.5	1.2
5	2.2	1.4	1.2	0.8	0.6	0.6
15	1.5	1.0	0.8	0.5	0.4	0.3
30	0.8	0.4	0.3	0.2	0.2	0.1
45	0.5	0.3	0.2	0.2	N/A	N/A
60	0.2	0.2	N/A	N/A	N/A	N/A
90	0.1	0.1	N/A	N/A	N/A	N/A

From Table 4.10, the Borehole water sample has already been treated which indicates chlorine disinfection is practiced for water distribution for the FUOYE Ikole campus, This explains the reason why the decay time is uniquely short. It is being dosed from the pumping machine.

From this thesis, we are critically looking at the decay that occurs after 30 minutes contact time, even though the decay test lasted for 90 minutes (1.5 hours). So, at 30 minutes, there should be no more than 2.0mg/l of free chlorine present in the water sample.

From the table shown above, only the initial chlorine dose of 3.0 mg/l was above the maximum permissible limit of 0.5mg/l. all other initial dosing concentrations from 2.5mg/l to 1.2mg/l already satisfied this condition at 30 minutes contact time.

At time 45 minutes, all the initial dosing from 3.0mg/l to 1.2 mg/l all shows the maximum residual chlorine of between 0.5mg/l and 0.2mg/l, while for initial dosing 1.5 and 1.2 mg/l showed N/D (non-detectable). At this time, permissible chlorine requirements limit by the NSWQW have been satisfied.

And by 90 minutes (1.5 hours), the residual chlorine measured 0.1mg/l for initial chlorine dose 3.0 and 2.5 mg/l. Dose 2.0 to 1.2 mg/l shows N/D.

Hence from this result **1.8mg/l** is the best dosage for sample B (borehole water) because it gives the shortest possible time to kill the germs present in the water (contact time). The optimum dosage is 1.8mg/l.

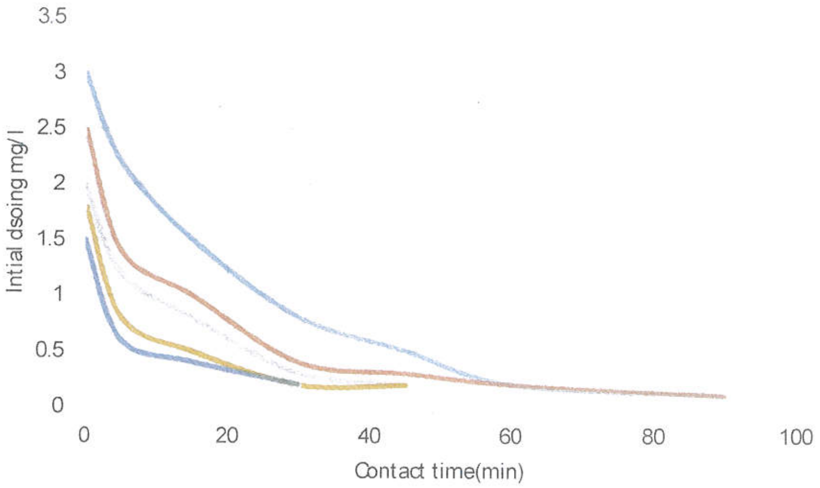


Figure 4.8: Chart of chlorine decay for sample B)

4.5 Chlorine Demand Test

Chlorine demand is an indicator of the amount of chlorine used up in a distribution system by the micro-organisms in water.

Table 4.11 show that chlorine demand is higher at the initial 60 minutes interval. More than 50% of the required initial chlorine is used up within this period. Lower demand rate is observed at later periods. Higher demand rate is also observed for higher initial concentration.

Table 4.12 shows that chlorine demand is higher at the initial 30 minutes interval. The initial concentration that will give a residual chlorine between 0.2- 0.5mg/l for the water samples.

Table 4.11: Chlorine demand test for SAMPLE A

Contact Time (mins)	**Initial Dosing (mg/l)**					
	3.0	2.5	2.0	1.8	1.5	1.2
0	0	0	0	0	0	0
5	0.4	0.5	0.2	0.4	0.3	0.4
15	0.8	0.6	0.4	0.6	0.5	0.3
30	1.0	0.7	0.5	0.8	0.7	0.6
45	1.3	1.0	0.8	1.1	1.0	0.6
60	1.6	1.1	1.0	1.3	1.1	0.9
90	1.8	1.1	1.2	1.4	1.2	0.9
120	1.8	1.2	1.3	1.4	1.2	0.9
240	2.0	1.7	1.5	1.5	1.3	1.0
360	2.5	2.0	1.6	1.6	N/A	N/A
480	2.6	2.3	1.9	N/A	N/A	N/A

Table 4.12: Chlorine demand test sample B

Contact	**Initial Dosing (mg/l)**					
Time (mins)	3.0	2.5	2.0	1.8	1.5	1.2
0	0	0	0	0	0	0
5	1.8	1.1	0.8	1.0	0.9	0.6
15	1.5	1.5	1.2	1.3	1.1	0.9
30	2.2	2.1	1.7	1.6	1.3	1.1
45	2.5	2.2	1.8	1.6	ND	ND
60	2.8	2.3	N/A	N/A	N/A	N/A
90	2.9	2.4	N/A	N/A	N/A	N/A

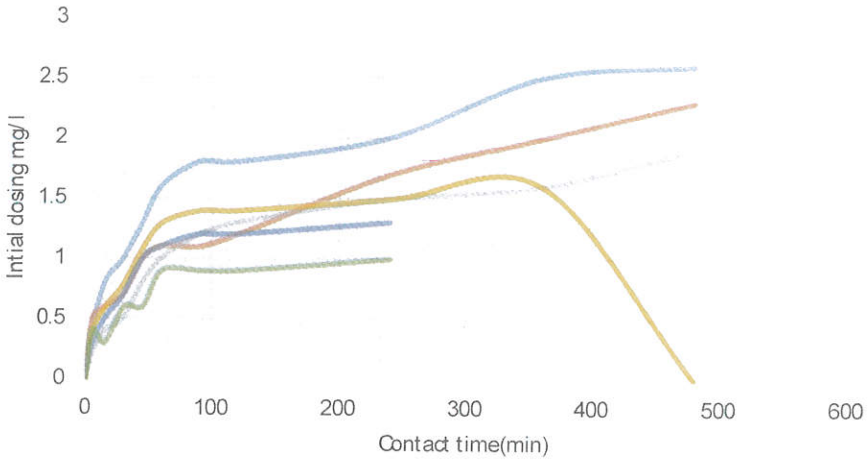


Figure 4.9: Chart of chlorine demand test for sample

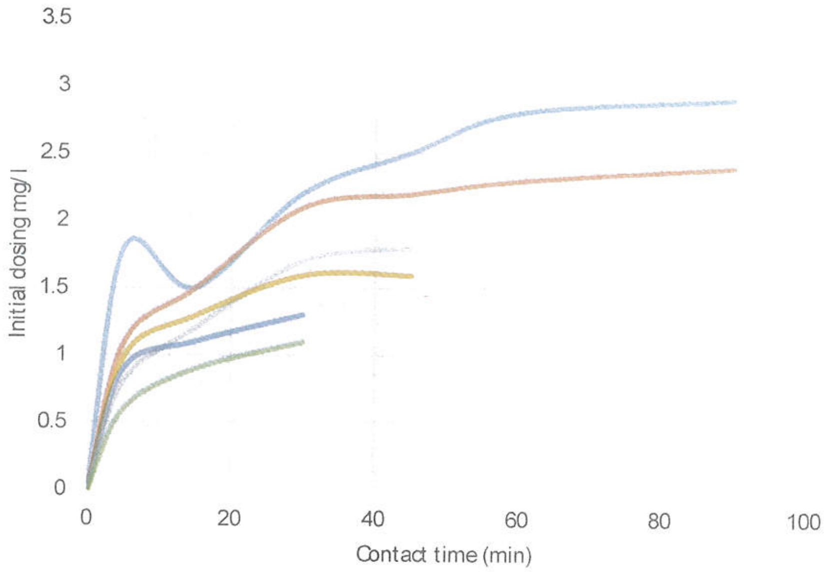


Figure 4.10: Chart of chlorine demand test for sample B

4.6 Comparison of the stream and borehole water

The significant difference in the physio-chemical qualities of the stream and borehole water sources of the study area were tested in the laboratory. This is done to ascertain, if there was any significant difference in the physio-chemical water quality parameters of the stream and borehole water sources supplied to Ikole campus.

Based on the results obtained from this study, the water quality of stream water sources differed from that of borehole water sources. These differences were observed from variations in the physio-chemical parameters analyzed from borehole and stream water sources. The stream water sources were found out to be more acidic and have highest turbidity (more turbid), salinity TSS concentration, dissolved content. Therefore, the drinking water quality of the borehole water sources is more preferable than the stream surface water sources.

For jar test of sample, A; JARS 5 and 6 are the only jars that is able to disinfect the water in the shortest possible time of 45 mins at a concentration of 1.5 and 1.2 mg/l respectively. JAR 6 is the only jar that is able to disinfect the water in the shortest possible time of 10 minutes at a concentration of 1.2 mg/l for borehole water sources.

Hence from this result 1.5mg/l is the best dosage for sample A (stream water), because it gives the shortest possible time to kill the germs present in the water (contact time) achieved at 45 min. The best dosage for sample B (borehole water) is 1.8mg/l because it gives the shortest possible time to kill the germs present in the water (contact time).

Chlorine demand for sample A (stream) is higher than that of Sample B.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The water quality assessment of groundwater and surface water samples from FUOYE community was analyzed to ascertain the suitable use of chlorine as a disinfectant for drinking water treatment within the community. The relevance of drinking water for the maintenance of a good health never be overemphasized, and from this study the following conclusions can be derived.

1. The stream source shows higher concentration of contaminants which could have been released from anthropogenic sources peculiar to the study area and hence require a high chlorine demand for adequate and effective disinfection than the second water source of borehole. Therefore, chlorine demand provides a use guide for the assessment of required disinfection treatment.

2. The study also shows the relevant parameter that contribute to high chlorine demand. One of such peculiar to our climate is temperature. This increases the decay rate leading to a reduced CT disinfection value.

3. This study also provides a good measure of CT disinfection for a bulk decay test. CT disinfection measures the required treatment useful for effective chlorination, and is a useful guide for surface and ground water treatment. Sample A indicates higher CT requirement than Sample B.

4. The quality of our drinking water affects us all; our health and our way of living all rely on having clean water resources. By protecting and our drinking water at its source through chlorine disinfection, we can help to preserve a healthy water supply for our present requirements and our future needs. Surface Water and groundwater is one of the main sources of drinking water and irrigation in FUOYE area. Its quality is getting deteriorated due to untreated discharge of rural and urban effluent.

5. The summary of the results of laboratory analysis conducted on the surface water shows that it requires further treatment before it can be suitable for drinking water.

5.2 Recommendations

1. The result of the study revealed that concentration of the contaminants in surface water is higher than the groundwater sources in FUOYE. This calls for serious concern, as the level of contamination needs remediation. To remedy the negative effect of the polluted water on the health of the inhabitants, the authorities concern should designate a properly treatment/chlorination system in the area, putting into consideration the groundwater and its flow directions.

2. Chlorine's wide array of benefits cannot be provided by any other single disinfectant. This includes lower cost, and it is readily available. The alternative disinfectants include chlorine dioxide, ozone, and ultraviolet radiation. All these disinfection methods have unique benefits, and limitations. Hence using chlorine as a disinfectant is cost effective and highly recommended.

3. Chlorine is more effective in reducing high concentrations of bacteriological parameters like BOD, COD, Total coliforms etc. It is also useful for the removal of taste, color and odor during water treatment, and therefore is a primary requirement for commercial water treatment.

4. More importantly, continuous testing of water quality composition of surface and groundwater in FUOYE Ikole campus water is encouraged. This is necessary since the inhabitant (FUOYE Hostel) in the area depend on ground water for drinking proposes.

5. Finally, all other recommendations may become inefficient without adequate monitoring.

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APPENDICES

Appendix A1: Questionnaire on water usage

FEDERAL UNIVERSITY OYE – EKITI (IKOLE CAMPUS)

DATA OF THE DIRECT WATER CONSUMPTION OF FUOYE (IKOLE CAMPUS)

This research questionnaire is for academic purposes with the objective of 'assessing and ***comparing individuals water quantity use and variability for different purposes (activities).*** View expressed in relation to this research remains confidential. I therefore entreat you to provide information as accurate as possible for true results. Thank you for your kind co- operation

Address of Respondent:	
Community	:

Section A

1 Sex

(a) Male ☐ **(b)** Female ☐

2 Residential Status

[a] On campus ☐ **[b]** Off campus ☐

3 Service level description

[a] No Access to water ☐ **[b]** Basic Access to water ☐
(1 km or 30 mins walk) (100-1000m or 5 – 30 mins walk)

[c] Intermediate Access ☐ **[d]** Optimal access to water ☐
(Single tap in yard) (Piped into home)

4 Source of water ____________________________________

Section B

USAGE	*WATER QTY (Litres)*	*DAILY*	*2X DAILY*	*WEEKLY*	*BI-WEEKLY*
Drinking					
Cooking					
Dish Washing					
Bathing					
Toilet Flushing					
Personal Hygiene					
Laundry					
Gardening					
Domestic Cleaning					
Miscellaneous					
TOTAL					

End of questionnaire thanks

Appendix A2: Data collection on population size in FUOYE – IKOLE Campus

Table A1: Data Collection on Population Size for Faculty of Engineering

	ABE	CPE	CVE	EEE	MEE	MET	MME	Total
2011/ 12	---	1	14	20	7	---	8	**50**
2012/ 13	7	12	12	16	13	--	14	**74**
2013/ 14	12	19	20	32	10	18	17	**128**
2014/ 15	14	34	33	44	22	23	16	**186**
2015/ 16	30	35	30	40	30	30	34	**229**
2016/ 17	40	60	64	65	46	48	48	**371**
2017/ 18	64	115	126	117	95	95	53	**665**

Table A2: Data collection on population size for faculty of agriculture

DEPT/ YEAR	**APH**	**CSH**	**FAQ**	**FST**	**HTM**	**SLM**	**WMA**	**Total**
2011/ 12	2	---	7	6	---	8	4	**77**
2012/ 13	10	---	11	22	---	12	10	**65**
2013/ 14	15	9	12	17	---	14	8	**75**
2014/ 15	16	12	14	15	---	14	9	**80**
2015/ 16	26	23	30	31	---	24	40	**174**
2016/ 17	36	27	20	36	68	41	36	**264**
2017/ 18	85	22	28	98	17	79	31	**360**

Table A3: Total number of students for each year in both faculty

Years	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18
No of Students	77	139	203	266	403	635	1025

Table A4: Total demand of water in Fuoye-Ikole Campus

Years	**No of students**	**Water demand(l/cap)**	**Staff demand**	**Total demand**
2011/2012	77	80	0.1	**1728**
2012/2013	216	80	0.1	**3352**
2013/2014	419	80	0.1	**5480**
2014/2015	685	80	0.1	**8360**
2015/2016	1088	80	0.1	**8704**
2016/2017	1723	80	0.1	**13784**
2017/2018	2748	80	0.1	**21984**