ACCESS TO IMPROVED WATER SUPPLY FOR DOMESTIC USE IN OOTUNJA IKOLE LOCAL GOVERNMENT, EKITI STATE

BY

ADAMOLEKUN, Oluwaseun Segun

(CVE/11/0365)

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ABSTRACT

This project is designed to determine households' access to safe water supply in Ootunja, Ikole-Ekiti, in terms of quality and quantity as the importance of improved water supply to human health cannot be over emphasized. However, safe/improve water supply to most Nigerian cities is still inadequate. In the study area the relationship between water quality, the degree of water source protection and quantity. This aim was achieved through the use of well-structured questionnaire in gathering information on time to water collect, distance from household to source, quantity collected, different water samples were collected and analyzed in the laboratory to measure the quality of the water that is being used for domestic activities in Ootunja, Ikole-Ekiti house-hold and it was compared the World Health Organisation standards for drinking water parameter which are the physical parameter, the chemical parameter and micro-biological parameter. Results showed that sample A did not meet the required drinking water quality standards for the physical and chemical parameter while all other water samples met the chemical parameter as they all fall within the permissible value of the W.H.O chemical standard. Also all the water sample did not meet the micro-biological W.H.O standard. The water samples were all contaminated with Aerobic mesophilic organism and coli form organism, Laboratory results also showed that in sample A,B,D aerobic mesophilic organism were too numerous to count. It was concluded that the study area has access to enough water quantity based on W.H.O standard It was recommended that NGOs/funding agencies should participate in development of improved water supply programmes and a lot of awareness creation activities should be done on sanitation and hygiene through extension workers.

Keywords: access, improve, water, supply, Ootunja, Ikole-Ekiti, Nigeria.

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Finally my supervisor, DR.(MRS). O.I Ndububa for all her advises and to my lecturers as well my fellow students for their humanly attention and lovely gestures.

DEDICATION

This Project is solely dedicated to Almighty God for the wisdom and strenght he gave to me during the reseach period

CERTIFICATION

This is to certify that this Project was prepared by ADAMOLEKUN, Oluwaseun Segun (CVE/11/0365) under my supervision, in partial fulfillment of the requirement for the award of Bachelor of Engineering (B.Eng) in Civil Engineering, Federal University Oye-Ekiti, Ekiti State, Nigeria

.... 06 OCT 2016

DR.(MRS). O.I Ndububa

Project Supervisor

.... 13/10/2016

Prof.J.B Adeyeri

Head of Department

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CHAPTER ONE
INTRODUCTION

1.1 Background

Nigeria is one of the member countries that adopted the millennium development declaration with its main objective of poverty reduction (UNDP, 2008). This resulted in prioritizing accessibility to improved water supply. Prior research has revealed that access to clean water, sanitation and hygiene are the significant elements for poverty alleviation (Water Aid, 2009). Access to safe drinking water and sanitation is a global concern. However, developing countries, like Nigeria, have suffered from a lack of access to safe drinking water from improved sources and to adequate sanitation services (WHO, 2006). As a result, people are still dependent on unprotected water sources such as rivers, streams, springs and hand dug wells. Since these sources are open, they are highly susceptible to flood and birds, animals and human contamination. In addition, most sources are found near gullies where open field defecation is common and flood-washed wastes affect the quality of water.

According to an ADF (2005) report, the Millennium Development Goals (MDG) objective of Nigeria is to increase the safe/improved water sources coverage from 2004 levels of 25% water supply and 8% sanitation to 62% for water supply and 54% sanitation by 2020. As a consequence, governmental and nongovernmental organizations made efforts to construct improved sources to provide access to safe and potable drinking water. Despite these efforts, improved water sources are often located far from user households, and due to the undulating nature of the country. Topography, water sources often occur at inconvenient locations, forcing people to travel long distances over continuous short and long steep slopes. These factors lead to less access to water needed by the household for consumption and forced households to seek out alternate unimproved and unhealthy nearby water sources due to reluctance in using improved sources. It is common that people who are most vulnerable to water-borne diseases are those who use polluted drinking water sources. The report from UNICEF (2010), in the world 884 million people use unimproved drinking water sources in 2010, and in 2015 estimates about 672 million people will still using unimproved drinking water sources. The WHO (2000) revealed that seventy five percent of all diseases in developing countries arise from polluted drinking water. The lack of access to water also limits sanitation and hygiene practices in many households because of the priority given for drinking and cooking purposes. Water quality concerns are often the most important component for measuring access to improved water sources. Acceptable quality shows the safety of drinking water in terms of its physical, chemical and bacteriological parameters (WHO, 2004). User communities" perceptions of quality also carry great weight in their drinking water safety (Doria, 2010). Depending on their perception on taste, odor and appearance (Sheat, 1992; Doria, 2010), this can lead to having different opinions about the aesthetic values of water quality. Consumer perceptions and aesthetic criteria need to be considered when assessing drinking water supplies even though they may not adversely affect human health (WHO, 2004).

Despite the best governmental and nongovernmental efforts, a large percentage of the water supply schemes are malfunctioning, forcing consumers to use unprotected sources that pose health hazards and which thus seriously affect their productivity. It is imperative to ensure that the water supply and sanitation services are adequate, affordable and reliable. The study was conducted in Amhara region Simada district where many governmental and nongovernmental efforts focused on water supply projects. Despite the opportunity for urban inhabitants to use tap water stands installed in the past few years, people are still collecting water from previously used distant water sources because of dissatisfaction with the change in the taste of the water, low income and longer waiting time as compared with the old protected springs. As a result of this dissatisfaction, consumers generally expect their water to have little or no flavor. People can detect variations in pH, mineral and organic content of drinking water (Dietrich, 2006). The variation in pH is detected indirectly, with greater acidity increasing corrosivity that in turn can contaminate the water, and which implies a change in the taste of water. In contrast, even though many water points have been built by different implementing projects in many areas, drinking water scarcity is still a great problem. Distance from the source to the house, waiting time, adequacy, quality and early failure of the scheme are common phenomena which force households to seek alternative unimproved water sources.

1.2 Justification

Creating community awareness of their water supply and sanitation services is one of the options for improving sustainable access (Mtinda, 2007). Improving the water supply coverage and quality has a number of consequences in addition to the fact that investigating the socioeconomic and other factors affecting household water consumption patterns provides guidance for policy makers and those in various agencies implementing projects. It also ensures the projects capture the major points to be considered before installation begins and ensures the ongoing provision of a service that is fundamental to improve health, reducing the burden of women and children carrying water long distances, and enabling users to live a life of dignity. Water supply and sanitation services should not be seen as isolated factors (Water Aid, 2009).

Furthermore to achieve the MDGs of access to improved water sources is better to incorporate each element to understand and recommend the major factors which hinder the vision of the long term programs for the provision of safe or quality water and sanitation services is very crucial.

1.3 Problem

Lack of access to safe and clean water is locked in the heart of the poverty. Even though the issue of water is observed as a general problem for both the urban and the rural population, women bear the greatest burden because of their social gender roles including collecting water for their households (Rose, 2009). Because of their task of water provision at the households, women and children suffer from disease have limited participation in education, and both income generating activities and engagement in cultural and political issues are often compromised.

Several studies have been carried out to analyze people's perception and attitude about the drinking water source quality and accessibility. Creating good community awareness about water quality issues and the associated problems like sanitation and hygiene services is important to alleviate health effects but it remains below the expected rate of coverage.

By the year 2015 the national water supply and sanitation program under its millennium development goal planned to increase the coverage of water supply and sanitation by 64% and 54% respectively. It has been said that the chances of achieving the Millennium Development Goal of halving the proportion of people without access to safe water by 2020 will be seriously lowered unless levels of sustainability can be greatly improved (Haysom, 2006; Harvey et.al, 2007).

1.4 Aims and Objectives

The main aim of this project is to assess access to safe/improve water supply for domestic uses.

The specific objectives are:

1. To assess the presence of alternative water sources used.
2. To assess the time required and distance individuals must travel to access water sources for households.
3. To assess the demand pattern improved sources at the household.
4. To assess the relationship between water quality, the degree of water source protection and sanitation behaviors.
5. To determine how community perception on water quality is related to the actual measured water quality.
6. To determine the key factors contributing to the continued use of unimproved water sources.

1.5 Population & Geographical Landscape of the 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.1.1 . Its neighbours are

Kwara State to the North, Kogi State to the North east, Ekiti East to the East, Gboyin Local Government in the South and Oye Local government in the West. The headquarters of the local government, Ikole-Ekiti is about 40 kilometres from Ado – Ekiti, the Ekiti State capital. 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; Male:87,976; Female: 80,460.The Local Government is predominantly a homogenous society and carefully populated by Yoruba speaking people of the South West Zone of Nigeria. The Religious of the people are mainly Christian and Islamic religious while a percentage of the people are Traditional religion worshippers. The place in the Ikole Local Government that attracts tourists from all over is the Itapaji Water Dam, Itapaji-Ekiti. ekitistate.gov.ng(2016)

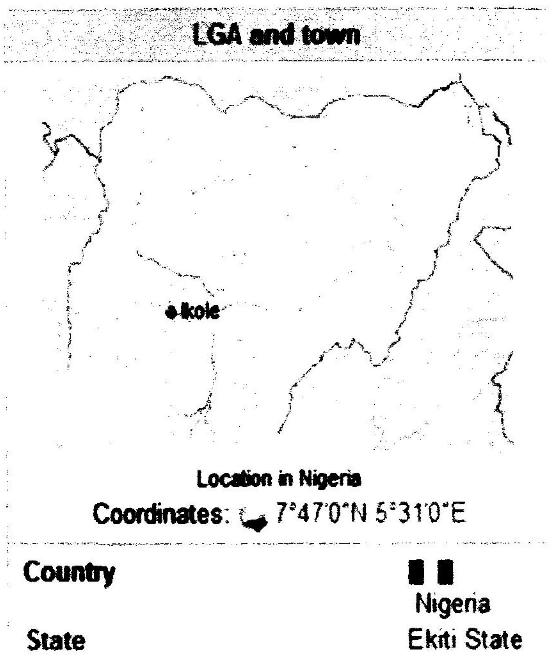

Fig 1.1 .Ikole-Ekiti on the map of Nigeria

1.5.1 Climate and Vegetation

Ikole is situated in the deciduous forest area of the State. Rainfall is about 1,778 mm per annum. Rain starts in March and peters out in November. The good drainage of the land makes it very suitable for agricultural pursuits. It is a common feature that trees shed their leaves every year during the dry season which begins in November and ends in February. The two seasons – Dry Season (November – February) and Rainy Season (early March – mid November) are quite distinct and they are very important to the agricultural pursuits of the people.

1.5.2 Sources of water in Ikole Local Government

1) Hand dug wells,
2) Bore-holes (pumped by powered machines and hand pump),
3) Surface water in form of streams,
4) Public Water Works (Itapaji dam),
5) Rain water harvesting

CHAPTER TWO
LITERATURE REVIEW

Water is needed for the maintenance of health. Its importance is not only related to the quantity, but also the quality. Access to water in the required quantity is needed to achieve good personal and domestic hygiene practice Huttly et al (1997), while good quality water ensures that ingested water does not constitute a health hazard, even in a life time of consumption Ezzati et al (2003). It is however estimated that as much as 1.1 billion people do not have access to safe drinking water UNICEF 2000, while the drinking of contaminated water is responsible for 88% of the over four billion cases of diarrhoeal diseases that occur in the world every year, and the 1.8 million deaths that result from them. It is also indirectly responsible for the 50% of childhood malnutrition that is linked to diarrhoral diseases, and the 860, 000 deaths that result from them each year Prüss-Üstün et al (2008)

The United Nations Millennium Declaration confirmed the central role of water in sustainable development and the major contribution that expanded access to safe water for domestic use World Health Organization (WHO) 2004. Water infrastructure stands out of all infrastructures (Physical and Social) as critical to the attainment of the MDGs. This is because beside goal number 7 and target 10 which are specifically water based, issues addressed by goals 1-7, in general, directly or indirectly relate to water availability". Therefore, meeting the water needs of Nigerians would be scores of ladder closer to attaining the overall MDGs. According to the African Water Development Report (AWDR 2006), in Africa, poor access to water and the attendant water scarcity affect women and girls disproportionately, the situation is worse in rural areas due to institutional and cultural barriers, including those of disparities in rights, decision-making power, tasks and responsibilities over water for productive and domestic activities. Infectious diarrhea is mainly responsible for the burden caused by water-borne and water-washed diseases. From the health perspective, improving access to safe water supply is a preventive intervention, whose main outcome is a reduction in the number of episodes of diarrhea and accordingly a proportionate reduction in the number of deaths. Consequently, water constitutes one of the primary drives of public health.

Table 2.1 Benefits of access to water supply

Beneficiary	Direct economic benefits of avoiding diarrheal disease	Indirect economic benefits related to health improvement	Non-health benefits Related to water
Health sector	-Less expenditure on treatment of diarrhea disease	-Value of less health workers falling sick with diarrhea	-More efficiently managed water resources & effects on vector bionomic
Patients	-Less expenditure on treatment of diarrheal disease and related costs; -Less expenditure on transport in seeking treatment -Less time lost due to treatment seeking	-Value of avoided days lost at work or at school -Value of avoided time lost of parent/caretaker of sick children -Value of loss of death avoided	-More efficiently managed water resources and effects on vector bionomics
Agriculture and industrial sectors	-Less expenditure on treatment of employees with diarrheal disease	-Less impact on productivity of ill health of workers	-Benefits to agriculture and industry of improved water supply, more efficient management of water resources – timesaving or income generating technologies and land use Changes

Source: WHO, 2004

As summarized on Table 2.1, the benefits of access to water in socioeconomic development is obvious, making access to water a major factor of human wellbeing. The benefit of access to water supply is monumental.

As shown in table 2.1, the benefits cut across health to general socio – economic issues. The realization of these and several other actual and potential benefits of water are hinged on an accessible water infrastructure. According to Adeyemo et al (2006), accessibility is the balance between the demand for and the supply of consumer services over a geographic space and narrowing or bridging the gap between geographic spaces is the all significance of transport. Access to vital resources and services has come to be recognized as positively related to development such that inaccessibility or lack of access is cited as lack of development or symptom of underdevelopment (Ayeni 1987). To the extent that, improved access to essential services has become an accepted part of the rubrics or measure of development and standard of living. Accessibility therefore establishes the extent to which factors like distance, time and cost have shrunk.

In urban areas the water source may be a public fountain or a stand pipe not more than 200 meters away. An adequate amount of water is that which is needed to satisfy metabolic, hygienic and domestic requirements usually about, at least 20 liters of safe water per person per day (UN-HABITAT 2003; World Bank 1997 in Meseret 2008). This minimum quantity, however, vary depending on whether it's an urban location or rural and whether warm or hot climate. Perhaps this is why the AWDR (2006), described basic water need of human beings to be 20 to 50 litres of uncontaminated water daily. The basic indicators for measuring water accessibility according to the WHO revolve around distance and time indices. These indicators show 4 paramount levels of accessibility; No access, for the worst scenario; Basic access; Intermediate access and Optimal access all on the basis of Time and Distance. The indicators as shown in table 2.2 would be a major basis for interpreting and assessing the level of water accessibility in the study area. Realistic measure of water accessibility is that which captures the three key indicators of, distance and time.

Table 2.2 World Health Organization (WHO) Water Accessibility Indicator

Travel distance to collect Water	(WHO) Standard	Average Time spent to collect water	(WHO) Standard
Water supplied Through multiple taps continuously	(optimal access)	Water supplied through multiple taps Continuously	Optimum access
<100 m	one tap on plot or within 100m (Intermediate access)	Within 5 minute	Intermediate access.
101-200m	Between 100 and 1000m	5-30 minute	Basic access
201-500m	(Basic access)	30 minute-2hours	
500m – 1000		2-4hours	
1.1-2km(1.5km)	More than 1000m	>4 hours	No access
>2km(3km)	(No access)		

Source: WHO, 2004

2.1 The Need for Water Supply

Access to water is a prerequisite for health and livelihood, which is why the MDG target is formulated in terms of sustainable access to affordable drinking water supply. The availability of improved and quality water supply and sanitation infrastructures are widely recognized as an essential component of human rights, social and economic development (ADF, 2005). The poor and marginalized people living- in rural and peri-urban settlements are most in need for improved and safe drinking water, appropriate forms of sanitation and access to water for other domestic purposes (Crow, 2001). Table 2.3 below shows the percent coverage of improved and unimproved water supply sources in developing country:

Table 2.3 : Improved and unimproved water supply sources coverage

Water sources	Urban (%)	Rural (%)
Household connection	61.6	3.0
Public stand post/pipe	33.2	20.9
Protected borehole or tube well	0.4	4.5
Protected spring or dud well	1.2	11
Collected rain water	0.0	0.3
Unprotected spring or dug well	1.5	31.7
Directly used from Pond water	2.0	28.6
Provided by tanker	0.0	0.0
Total	100	100

Source: WHO (2006), access to improved and unimproved sources

Even though improved water sources are available, they are often far away from the beneficiary households and are located at inconvenient locations. The management system of stakeholders coupled with water quality problems and inaccessible water sources are some of the basic problems (Demeke, 2009; Bhandari and Grant, 2007). In addition to that, the lack of safe water supply has other series negative consequences such as the workload in fetching unsafe water from mostly distant unimproved or traditional water points make them vulnerable to health problems. As a result, most of the children miss the opportunity of attending school, while women spend 10-50% of their daytime fetching water from polluted water points, losing time on productive activities (Water Resources Management Policy, 1999; Crow, 2001). According to WHO, basic access can be defined as the availability of drinking water at least 20 liters per day per person, a distance of not more than 1 km from the source to the house and a maximum time taken to collect round trip of 30 minutes. The UNDP (2008) says the minimum absolute daily water need per person per day is 50 liters (13.2 gallons) which include: 5 liters for drinking, 20 for sanitation and hygiene, 15 for bathing and 10 for preparing food. However because of scarcity of drinking water, millions of people try to exist on 10 liters (2.6 gallons) a day (ADF, 2005). In densely populated areas, a water hauling trip of 30 minutes or less, including queuing time would be a more appropriate indicator of access. As indicated by ADF (2005), over one third of women in some of the regions spent more than two hours for each water collection trip. This fact is aggravated by the poor supply efficiency, resulting from bad condition, which cannot satisfy the entire populations from different villages sharing the same water source and increased queuing time is common during the dry seasons (Admasu et al., 2002). This will ultimately lead to household water insecurity (less water available than is needed for drinking, cooking, and sanitation) in rural areas, especially for those households for which the demand is higher due to large family size (Collick, 2008, as cited by Demeke, 2009). Because of these conditions, it is difficult to think about personal hygiene and sanitation especially for the rural communities. Despite the scarcity of water, many give priority for drinking and cooking purposes. Rural communities use unprotected springs and hand-dug wells commonly for cooking and drinking purposes. Whereas rivers besides their use for washing clothes they also used for drinking purposes. This results in not only sickness and death, but also economic crises. Therefore, safe drinking water is an essential component of primary health care and is vital for poverty alleviation.

Introducing improved water supply sources at the household level enhance personal and community knowledge as well as awareness of the importance of other factors, such as hygiene and sanitation (Sobsey, 2002)

2.2 Concept of Domestic Water

Basically, domestic water refers to water consumed by the household and it uses varies with the climate and the stage of sophistication of the urban community Pereira (1973). It includes water for cooking, personal cleaning, drinking, flushing of lavatory, water of lawns and flowers, car washing and general house cleaning.

Ayoade (1988), in his work posits that the human body is 60% water and an average daily water intake of 2.25 liters is required by every person. Generally, there had been lack of information on the components of domestic water particularly in the tropics. But however, personal washing and flushing of closets account for almost 30% of water used by the households.

Isaac (1965) stipulates that an average man is entitled to 115 liters of water per day in the temperate region while Ayoade and Oyebande (1978) in their study of water situation in Nigeria states that an average individual requires 46 liters of water per day. Department of water affairs and forestry Merla (1994) in a recent report on water supply policy defines basic water supply as 25 liters per person per day at a good quality provided at a distance of 200m on a regular and assured basis.

Experience shows that people tend to use more water when they have access to running water. For instance U.S. average personal water use is about 600 liters per day compared with about 50 litres per capita per day in India. European Schoolbook (1994).

Keith (1993), Gleick (1993) and UN (1997) in their various study confirmed that domestic water is about 8% of the total water used worldwide. There is an upsurge in the quantity of water required for domestic purposes due to population increase and sophistication in the standard of living. The use of modern household appliances such as dish washing machine by the affluent ones in the society need enormous amount of water. European Schoolbook (1994).

White (1972) in their study of domestic water uses in East Africa, observed that the humidity of the courtyard may be enhanced through fountain or pools while large volume of water may go to irrigation of lawns and flowers for cooling effect or for esthetic enjoyment. A study conducted by Farror (1977) on domestic water use among low income communities in Nchixian Mexico reveals that the volume of water used by people of many developing countries is chiefly a function of income and material wellbeing, hence the affluent ones have access to sufficient
quantity of water.

McDonald and David (1988) supports the above point when he declared "in many urban centers,if one can afford the capital cost, clean piped water could be cheap enough for the rich to file their swimming pools, while the poor may have to pay two or three times as much, per unit quantity of water, to buy by the bucket from a tanker". The above preposition shows the disparity between the rich and the poor in the urban area.

2.3 What is meant by "access to safe/improved water"?

Access to safe water is measured by the number of people who have a reasonable means of getting an adequate amount of water that is safe for drinking, washing, and essential household activities, expressed as a percentage of the total population or it is the proportion of people living in an area that is using improved water source such as hand-dug wells and bore-holes that are well constructed (WHO/UNICEF, 2009).

The World Bank defines access to safe water, as the share of the inhabitants with reasonable provision to an ample quantity of safe water. Safe water includes treated surface water and untreated but uncontaminated water; water for ingestion, basic personal and domestic hygiene and cooking; excluding water for clothes washing e.t.c.

An improved drinking water source is defined as a type of drinking water facility or water delivery point that by the nature of its design protects the drinking water source from external contamination, (WHO/UNICEF, 2009), particularly or faecal origin and which can be piped into dwelling, plot or yard, public tape/stand pipe, tube well/borehole, protected dug well, rain water collection and protected springs (Van Norden 2007 as cited by Sutton, 2008). Unimproved sources include unprotected dug well, unprotected springs, tanker truck, surface water (river, dam, lake, pond, stream, and irrigation canal), and bottled water (Van Norden 2007 by Sutton, 2008).

Safe water is drawn from freshwater sources, which represent only 2.5% of the 1.4 billion cubic kilometers of water covering the earth. Less than 1% of this fresh water is safe to drink without prior treatment.Fewtrell L et al (2005) Safe drinking water can also be obtained from salt water through desalination. Monitoring organizations, under the supervision of the Joint Monitoring Programme (JMP),Clasen T et al (2005) define "safe drinking water" as water from an "improved water source," which includes household connections, public standpipes,
boreholes, protected dug wells, protected springs and rainwater collections. MGD (June 200)

2.4 SOURCES OF WATER

Water Source is potential raw water, i.e, it is natural fresh water that could be abstracted and processed for domestic purposes. The chemical composition of natural fresh water is the end result of rainwater that has fallen on to the land and interacted with the soil, the material in or on the soil, and rocks as it moves down rivers, or into lakes, or percolates underground. Its overall quality is further modified by run-off from various land uses (non-point or diffuse sources) and by discharges (point source). The quality is modified further by biological activity, wind-blown material and evaporation. DWSNZ (2015) the sources of water is basically two namely surface and underground source of water

2.4.1 Surface water

Surface freshwaters (rivers, streams, lakes and impoundments) comprise those natural waters that are open to the atmosphere and contain only relatively small quantities of dissolved materials; generally much less than 1000 mg/L (Harding et al 2004).

The convenience of having readily available and accessible sources of water rapidly renewed by rainfall is offset somewhat by the susceptibility of surface waters to pollution from a variety of diffuse and point sources. Point sources are clearly identifiable, have specific locations, and are typically pipes and drains discharging wastes (Davies-Colley and Wilcock 2004).

In most catchments used for water supply, pollution will be from diffuse sources, arising from land-use activities (urban and rural) that are dispersed across a catchment (Novotny 2003). Diffuse sources include surface runoff, as well as subsurface drainage, resulting from activities on land. The main categories of diffuse pollutants are sediment, nutrients and pathogenic micro-organisms. Other categories of diffuse pollutants are heavy metals (principally from urban land) and pesticides (mainly from agriculture and horticulture). Water UK (2012) summarizes helpful ideas for catchment protection.

A summary of human activities that impinge on the suitability of freshwaters for potable water is given in Table 2.4 Note that birds may be a significant source of faecal pollution in surface waters as indicated by standard faecal indicators (eg, E. coli), and shed pathogens (eg, Giardia cysts, Salmonellae and Campylobacter) (McBride et al 2002).

Table 2.4: Human activities and associated inputs into freshwater ecosystems with health risks

<table>
<tr><th>Activity</th><th>Contaminants</th><th>Health risks</th></tr>
<tr><td>Agriculture and horticulture</td><td>Sediments
Nutrients
Pesticides and other toxic chemicals and metals
Faecal microbial contaminants</td><td rowspan="5">Immune and endocrine disruption

Retarded physical and cognitive development, blue baby syndrome

Foetal malformation and death

Nervous system and reproductive dysfunction

Behavioural changes
Cancers
Waterborne disease</td></tr>
<tr><td>Industry</td><td>Nutrients
Toxic chemicals and metals
Oils</td></tr>
<tr><td>Mining</td><td>Sediments
Toxic chemicals and metals</td></tr>
<tr><td>Urbanisation, infrastructure and development</td><td>Sediment
Pesticides and other toxic chemicals and metals
Oils
Faecal microbial contaminants</td></tr>
<tr><td>Recreation</td><td>Oils and fuel
Toxic chemicals</td></tr>
</table>

Modified after Slaney and Weinstein 2004.

2.4.2 Groundwater

2.4.2.1 Description of a groundwater system

Unlike surface water, many of the processes that affect the quality of groundwater occur underground, out of sight, so cannot be observed directly. To know how a groundwater system works is largely obtained by deduction from indirect observation. The following sections describe the general characteristics of a groundwater system and the processes that can affect bore water quality.

Groundwater comprises about 80–90 percent of the world's freshwater resources. It is recharged from the surface, predominantly from rainfall, but can also receive leakage from rivers and lakes. Water seeps down through the soil and unsaturated formation until it reaches the water table. At this point it moves more horizontally through pores in sediments and fractures in rock. Aquifers are large areas of formation that act as reservoirs from which groundwater can be abstracted through a bore for supply. DWSNZ (2015)

Confined and unconfined aquifers

If a layer of relatively saturated impermeable material (an aquitard) overlies an aquifer, the system is known as a confined aquifer. The aquitard acts as a protective layer, often minimising or preventing further vertical movement of contaminants into the aquifer. Aquitards can also reduce the vertical interchange of water between aquifers at different depths. Where an aquitard is lacking (eg, tapers out) an aquifer may be more vulnerable to contamination from the ground surface ie, no longer confined, or springs can emerge at the ground surface. Springs can be contaminated directly from surface sources, and can act as conduits for contaminants to move down into the underlying groundwater particularly if they dry out during dry periods.

An unconfined aquifer is so called because of the absence of a confining aquitard layer (eg, clay). In contrast to a confined aquifer, it is relatively vulnerable to contamination from the land surface. For the purposes of the Drinking-water Standards 2005 (revised

2008) (DWSNZ), when planning a drinking-water quality monitoring programme, unconfined groundwater systems less than 10 m deep should be regarded as being probably no safer than surface sources.

2.5 Water quality parameters

Domestic water, or potable water, is defined as having acceptable quality in terms of its physical, chemical, bacteriological parameters so that it can be safely used for drinking and cooking (WHO, 2004). WHO defines drinking water to be safe if and only if no any significant health risks during its lifespan of the scheme and when it is consumed.

2.5.1 Perception of drinking water

In terms of drinking water quality, user perception is one of the most important things, sometimes exceeding actual quality of water especially when it concerns the quality of drinking water for the user communities (Sheat 1992, Doria 2010). There are different factors that influence the perception of drinking water quality, including:

1. Human sensory perceptions of taste, odor and color of water are related with mental factors and some extent taste, which is the more important because it may detect water contamination related to chemicals.
2. People may perceive risks if they experience health problem caused by water.
3. Experience with the previous water source status based on its taste, color and odor change. For example the change in the color of water from yellowish to bluish may feel that the water is perceived not good water (Doria, 2010).
4. Information plays a great role in changing people"s perception on the water source behavior. It may be person to person or using media (like news papers, brochures etc.) but in rural areas and poor urban residents interpersonal information is important.

2.5.2 The Quality of Groundwater

Ground waters are generally of better microbiological quality than surface waters because of the range of mechanisms active under the ground that can attenuate the microbial contaminants initially present in the water. Moreover, changes in microbiological quality that occur are not as large or as rapid as those in surface waters. Although some aspects of the chemical quality of ground-waters may be a concern, these characteristics of the microbiological quality of groundwater often mean they are more preferable source waters than surface waters. However, once a groundwater becomes contaminated by chemicals, it takes a long time before the contamination is flushed out.

Table 2.5, copied from the WHO Guidelines for Drinking-water Quality (2004), provides a comparison of the levels of pathogens and indicator organisms found in surface and groundwaters.

Table 2.5 : Concentrations of enteric pathogens and indicators in different types of water sources

Pathogen or indicator group, per litre	Lakes and reservoirs	Impacted rivers and streams	Wilderness rivers and streams	Groundwater
Campylobacter	20–500	90–2500	0–1100	0–10[a]
Salmonella	–	3–58,000 (3–1000)[b]	1–4	–
E. coli (generic)	10,000–1,000,000	30,000–1,000,000	6,000–30,000	0–1000
Viruses	1–10	30–60	0–3	0–2
Cryptosporidium	4–290	2–480	2–240	0–1
Giardia	2–30	1–470	1–2	0–1

a Should be zero if bore water secure.

b Lower range is a more recent measurement.

Ground waters are not usually in direct contact with faecal material, as surface waters may be, but rainfall and irrigation provide means by which surface contamination can be carried into the groundwater. In some countries groundwaters have been contaminated by the very bad practice of pumping wastes down disused bores. The vulnerability of aquifers to microbial contamination is increased by (Sinton 2001):

1. Recharge water coming into contact with microbial contamination.
2. higher porosity aquifer media, which allow greater penetration and transport of microbes,
3. shallow aquifer depth
4. absence of a confining layer
5. Light overlying soils and porous subsoil strata, which reduce the efficacy of processes removing microbes in these layers.

In many areas of the world, aquifers that supply drinking-water are being used faster than they recharge. Not only does this represent a water supply problem, it may also have serious health implications.

The layer of unsaturated soil above the groundwater plays a major role in reducing the numbers of micro-organisms found in groundwaters. Factors affecting the survival of organisms (ie, how rapidly the organisms die off), and those influencing their transport (ie, how quickly they are carried through the unsaturated strata) both affect the levels of microbes reaching the groundwater. Bacterial survival in soils is improved by the following (Sinton 2001):

1. high soil moisture
2. greater penetration into the soil profile
3. low temperatures
4. low pH values (in the range 3–5)
5. high organic matter content
6. low numbers of antagonistic soil microflora.

The most important attenuating processes for bacteria in soils are filtration and adsorption (Sinton 2001). The effectiveness of filtration is greatest in soils with low particle size, while some sedimentation can occur in zones where there is virtually no flow of water. Media providing large surface areas, such as clays, improve contaminant adsorption. The adsorption process is enhanced by conditions that minimise electrostatic repulsion between the micro-organism and surfaces to which they might adsorb. Increased levels of dissolved solids in the water assist in suppressing electrostatic repulsion, consequently rainwater, which contains little dissolved material, assists microbes in penetrating further into the ground. Organisms can be found at great depths. Microbes and invertebrates can be found in openings 100 metres or more beneath the surface. Bacteria can exist in some groundwater thousands of feet below the land surface. However, invertebrsates are typically found within 1 to 10 metres of the surface in consolidated materials, in what is called the hyporheic zone. Within this shallow groundwater zone, many macroscopic invertebrates have been identified. Furthermore, the species richness and community structure of these organisms has been shown to change with alterations in groundwater quality. Therefore, the relative presence or absence of different communities or populations of organisms may reflect the impact of changes in regional groundwater quality. As a result, the organisms living within the shallow groundwater zone can serve as indicators of the quality of the groundwater resource. Macroinvertebrates living in the hyporheic zone, such as oligochaetes, isopods, and ostracods, have evolved special adaptations to survive in a food-, oxygen-, space-, and light-limited environment (USEPA 1998). Sinton (1984) described macro-invertebrates observed in a polluted Canterbury aquifer.

2.6.1 Chemical Parameters

Some of the main chemical parameters that are of a health concern include the following WHO (2004):

1. Fluoride causes mottling of teeth and in severe cases can result in crippling skeletal fluorosis.

2. The presence of arsenic implicates the risk of cancer and skin lesions.

3. Nitrate and nitrite can cause methaemoglobinaemia. This arises from excess fertilizers or leaching of wastewater and other organic wastes into water surface.

4. Lead can have adverse neurological effects, mainly in areas with acidic waters and the use of lead pipes, fittings and solder.

Secondary concern of the impact of chemical constituents is the effect on distribution and treatment systems that may be implemented to improve the access to a safe water supply. Corrosive properties of constituents can induce structural failure, which can also result in deterioration of the quality of the water and cause additional concerns for health and safety. Due to these concerns, corrosion control is an important aspect of the management of a drinking water system pH can Control the solubility and reaction rates of most metal species involved in corrosion reactions (WHO, 2004). Iron, lead, copper, brass and nickel can also be used in construction of piping systems (WHO, 2004). Concrete is a composite material consisting of sand, gravel and cement, a binder consisting primarily of calcium silicates, aluminates and some lime (WHO, 2004).

Structural deterioration or failure of cement may result from prolonged exposure to aggressive or highly corrosive waters which can result in leaching of metals from the cement into the water (WHO, 2004). When ferrous iron oxidizes to ferric iron, it can give a reddish-brown color to the water, which could be aesthetically displeasing (WHO, 2004).

Manganese can cause an undesirable taste as well as staining laundry when levels exceed 0.1 mg/liter. The presence of manganese may also lead to the accumulation of deposits in the piping system (WHO, 2004). There is no health-based guideline value set for iron but for manganese it is four times higher than the acceptable threshold of 0.1 mg/liter (WHO, 2004).

High nitrate concentrations occur in domestic-water. It has a number of possible sources, all related to human activities, such as: fertiliser application; disposal of wastewater from dairy factory operations; high grazing densities of dairy stock. It can also be found at high concentrations on a localised scale due to on-site waste disposal systems (eg, septic tanks). Ammonia is the commonest nitrogen compound in anaerobic water.

There is typically an increased leaching of nitrate from soils with increased rainfall or rising water table levels. In these cases, the highest nitrate concentrations will be found when the water table is highest, ie, usually in the winter and spring,www.landcareresearch.co.nz/science/soils-and-landscapes/ecosystem-services/factsheets.

Fluoride is often found as a groundwater contaminant of health significance, but fluoride in excess of 50 percent of its MAV has been found in only three water supplies (Ritchie 2004). Slightly elevated levels of fluoride can found in geothermal areas, and in some geo-thermally influenced (hydrothermal) waters.

Manganese is a health-significant determinant, but it can also adversely affect the aesthetic properties of water. It is a naturally-occurring determinant, which dissolves into groundwater under oxygen-deficient, low pH conditions. Such conditions often arise in shallow ground waters as the result of the respiration of microbes in the sub-surface media through which the water passes. During respiration organisms withdraw oxygen from the water and return carbon dioxide as a waste product. The carbon dioxide dissolves to form carbonic acid, thereby depressing the pH of the water and dissolving the manganese, particularly when the water is anaerobic. Some source of organic matter, such as peat, may be associated with the appearance of manganese, as the organic matter provides a source of carbon, which is required as a nutrient by the microbes.

Iron, which is of aesthetic but not health importance, is also mobilised from minerals under conditions similar to those that will mobilise manganese, and the two are often found together. The conditions that lead to the appearance of iron and manganese can be verylocalised. New groundwater sources should therefore be tested for both metals, rather than relying on results from nearby bores as an indicator of likely water quality. Iron and manganese concentrations may also vary significantly with time, particularly in shallow unconfined groundwater.

Calcium and magnesium are two major cations that can occur at high concentrations in groundwaters that have been in contact with calcareous rocks, such as limestone (chalk) and marble. These cause water hardness, which can lead to problems of scale formation on hot surfaces, and difficulty in getting soaps to lather.

2.6.2 Bacteriological Parameters

The diseases caused by water related microorganisms can be divided into four main categories:

1. Water-borne diseases: caused by water that has been contaminated by human, animal or chemical wastes. Examples include cholera, typhoid, meningitis, dysentery, hepatitis and diarrhoea. Diarrhoea is caused by a host of bacterial, viral and parasitic organisms most of which can be spread by contaminated water (WHO, 2006). Poor nutrition resulting from frequent attacks of diarrhoea is the primary cause for stunted growth for millions of children in the developing world (Gadgil, 1998).

2. Water-related vector diseases: These are diseases transmitted by vectors, such as mosquitoes that breed or live near water. Examples include malaria, yellow fever, dengue fever and filariasis. Malaria causes over 1 million deaths a year alone (WHO, 2006). Stagnant and poorly managed waters provide the breeding grounds for malaria-carrying mosquitoes.

3. Water-based diseases: These are caused by parasitic aquatic organisms referred to as helminths and can be transmitted via skin penetration or contact. Examples include Guinea worm disease, filariasis, paragonimiasis, clonorchiasis and schistosomiasis.

Water-scarce diseases: These diseases flourish in conditions where freshwater is scarce and sanitation is poor. Examples include trachoma and tuberculosis

Testing the bacterial contaminants in water can be simplified by utilizing the presence of an indicator organism. An indicator organism may not necessarily pose a health risk but it can be easily isolated and enumerated, is present in large numbers, is more resistant to disinfection than pathogens, and does not multiply in water and distribution systems (Gadgil, 1998). Traditionally, total coliform bacteria have been used to indicate the presence of fecal contamination; however, this parameter has been found to exist and grow in soil and water environments and is therefore considered a poor parameter for measuring the presence of pathogens (Stevens et al., 2003). Studies also show that due to their ability to grow in drinking water distribution systems and their unpredictable presence in water supplies during outbreaks of waterborne disease, the sanitary significance or quality of water is difficult to interpret in the presence of total coliforms (Stevens et al., 2003). An exception is Escherichia coli (E.coli), a thermotolerant coliform, the most numerous of the total coliform group found in animal or human feces, rarely grows in the environment and is considered the most specific indicator of fecal contamination in drinking-water (WHO, 2004). The presence of E. coli provides strong evidence of recent fecal contamination (WHO, 2004, Stevens et al., 2003).

The risk of coliform presence can depend on the health or sensitivity of the consumer. The risks of E. coli presence, slightly greater than WHO Guideline's zero count per 100ml may be of only low or intermediate risk. According to IRC, 2002 as cited by Michael H., 2006 about risk classification for thermotolerant coliforms or E. coli of rural water supplies shown below in table 2.6.

Table 2.6: water quality counts per 100mL and the associated risk

Count per 100ml	Risk Category
0	In conformity with WHO guidelines
1 – 10	Low risk
11 – 100	Intermediate risk
101 – 1000	High risk
> 1000	Very high risk

2.6.3 Physical and aesthetic parameters

Consumer perception and acceptability of their drinking water quality depends on user sense of taste, odor and appearance (Sheat 1992; Doria 2010). That is why consumers have differing opinion about the aesthetic values of water quality. Relying on their own senses may lead to avoidance of highly turbid or colored but otherwise safe waters in favor of more aesthetically acceptable but potentially unsafe water sources (WHO, 2004).

Taste and odor can originate from various natural chemical contaminants, biological sources, microbial activity, from corrosion or as a result of water treatment (e.g. chlorination) (WHO, 2004). Color, cloudiness, particulate matter and visible organisms can also contribute to unacceptability of water sources. These factors can vary for each community and are dependent on local conditions and characteristics. The following lists a number of primary aesthetic indicators that can cause water to be perceived as unacceptable:

1. True color (the color that remains after any suspended particles are removed);
2. Turbidity (the cloudiness caused by particulate matter present in source water, re suspension of sediment in the distribution system, the presence of inorganic particulate matter in some groundwater or sloughing of bio-film within the distribution system (WHO, 2004).
3. unusual taste, odor and „feel" problems (usually due to total dissolved solids)

Turbidity is the most important problem for the aesthetic value of water quality. Although it doesn't necessarily adversely affect human health, it can protect microorganisms from disinfection effects, can stimulate bacterial growth, and indicate problems with treatment processes (WHO, 2004). For effective disinfection, median turbidity should be below 0.1 NTU although turbidity of less than 5 NTU is usually acceptable to consumers (WHO, 2004). An important operational water quality parameter is pH, although within typical ranges it has no direct impact on consumers. Low pH levels can enhance corrosive characteristics resulting in contamination of drinking-water and adverse effects on its taste and appearance (WHO, 2004). Higher pH levels can lead to calcium carbonate deposition. Careful consideration of pH is necessary to ensure satisfactory water disinfection with chlorine, which requires pH to be less than 8 (WHO, 2004).

Total dissolved solids (TDS) and electrical conductivity (EC) are measures of the total ions in solution and ionic activity of a solution respectively. As TDS and EC increase, the corrosive nature of the water increases.

2.7.1 Water treatment plants: The water treatment plant provides chemical treatment in the form of coagulation of suspended solids, screening or filtering, corrosion control, and chlorination. These processes result in high quality, potable water. The principle of operation is that the water enters the plant; chemicals are added; mixing, sedimentation, and filtration follow; then final adjustment of the water is provided for corrosion control and disinfection. Details of design of these appurtenances are as follows:

Mixing process: One of the most important processes in water treatment is the mixing process whereby the added chemicals are mixed in proper proportion to the incoming water, thus causing precipitation. Mixing may be done by hydraulics or by mechanical equipment:

a) **Baffle mixing:** Acceptable practice for a baffle mixing basin, either around-the-end or over-and-under, is that a velocity of 1.5 feet per second be maintained for the first third of the basin, a velocity of 1.75 feet per second through the last third. In many cases, a flash mechanical mixer at the entrance of the baffled basin will assist in the coagulation process. The flash mixer should have a shaft speed of 350 to 750 revolutions per minute (rpm) and the time of the mix should be from 1 to 5 minutes.

b) **Mechanical mixing:** Mixing should be adequate to disperse the chemicals thoroughly in the raw water prior to its entrance into the flocculation basin. If the mix is done by high-velocity mixers, such as by pump or turbine-type mixer, the velocity should be 5 feet per second or greater, and the retention time should be 1 minute, more or less. If a flash mixer is used, it should be as discussed above under baffle mixing. Paddle-type mixers equipped with variable speed regulators should provide a peripheral speed of 1 to 3 feet per second and a retention time of not less than 5 minutes.

Air mixing devices provide benefits in addition to agitation or mixing of the chemicals. Air being blown through the basin provides this additional treatment in the removal of taste and odors from the water. It also provides oxidation of iron and manganese to aid in their removal. Air mixing units should be designed to provide three stages of agitation: violent, intermediate, and quiescent. The requirement of the air supply is at least 0.5 cubic feet or air per square foot of tank area or 0.05 to 0.20 cubic feet of air per gallon of water. The time of aeration contact of the water should be from 10 to 30 minutes. Air mixing devices may be used in conjunction with either baffle or mechanical mixers. The final step of mechanical mixing is that of mechanical flocculation, that is, the slow agitation of the fine flox to hold it in suspension so that the size may build up before the sedimentation process. Mechanical flocculators should be of variable speed, with the peripheral speed of the paddles being from 0.5 to 2.0 feet per second. The basin should be sized to provide a retention period of from 20 to 40 minutes.

All conduits carrying coagulated water to the sedimentation basin should be designed to provide a velocity of 0.5 to 1.0 feet per second. Less than 0.3 feet per second, the floc will settle, while at greater than 1.0 feet per second, it will be broken up. Therefore, the 0.5 feet per second is considered the optimum velocity for coagulated water.

Sedimentation basin: The sedimentation basin is provided for the removal of the floc from the coagulation process. In a well-operated plant, the majority of the purification process takes place in this coagulation process. Therefore, the design of this basin is of importance. The sedimentation basin consists of a diffusion wall and the basin itself. The diffusion wall acts to diffuse the floc over the entire width of the basin. It should be located from 5 to 10 feet from the end of the basin. The size and number of the slots within the wall should be based on a velocity of 0.4 to 0.8 feet per second through the slots and to provide uniform distribution and velocity across the basin. The diffusion wall may be omitted, provided that other methods are used to give this uniformity of distribution.

The sedimentation basin should provide a theoretical detention period of at least four hours. The velocity of flow through the basin should be from 0.3 to a maximum of 1.0 feet per minute. The length-to-width ratio of the basin should be from 2 to 1 to a maximum of 3 to 1. The depth of the basin should be from 10 to 16 feet.

The bottom of the basin should be sloped to a drain sized to empty the basin within a period of 4 hours. An independent overflow should be provided for each basin. The outlet device for settling tanks should be either of the submerged weir-type or large openings to prevent high velocities.

Solids contact or up-flow units: In fairly recent years, the solids contact or up- flow unit has come into use. This compact unit provides chemical mixing and sedimentation where the settled floc is recirculated to mix with the newly formed floc, thus providing a heavy floc for settling. This type of unit also provides for continuous sludge removal by an automatic timing device. Even though these units have been used in the water softening processes for many years, their application to clarification of turbid waters for community systems requires care in design and operation.

The maximum rise rate of the clarification of water should be in the range of 1.00 to 1.25 gpm per square foot of clarification area. In certain instances where the quality of raw water contains a high concentration of hardness, the rise rate may be increased to 2.25, but in doing so considerable study should be made of the year-round water quality.

The detention period for this type of treatment unit should not be less than 2 hours, with a mixing and flocculating zone averaging not less than 35 minutes. At the greater rise rates, the detention period may be lowered accordingly, but not less than 1 hour. The mixing device should be a variable speed type agitator with a ratio of 2 to 1, and should be designed so that there will be no dead space in the bottom zone of mixing. Sludge removal from the unit should be somewhat continuous, with the sludge removal mechanism controlled by an adjustable automatic timer. The effluent weir of the unit should provide for uniform collection of the clarification area at a lead not to exceed 7 gpm per foot of weir length.

Rapid gravity sand filters: Sand filters provide the final treatment for the removal of suspended matter for the water. Filtration as a treatment process provides greatest efficiency when a layer of floc creates a mat on the sand surface to filter through. Sand filters are designed on the basis of filtration and backwash rate. The filtration rate is established at 2 gpm per square foot of filter area. In certain instances, this rate may be increased to 3 gpm per square foot of filter area, in which case the plant design and operation must be extremely good that the backwash water rate is established at 24 inches rise per minute. This will give a flow of 15 gpmper square foot of filter area. When Anthrafilt is used, the backwash rate should be around 18 inches rise per minute. To meet these two flow conditions, the filter underdrain and other controls must be designed properly.

For proper operation of a filter, proper controls and gauges must be installed on the filter. These include rate-of-flow controller, loss of head gauges, rate of flow gauges, and wash water rate gauges. Filter bottoms must be adequate to provide filtration and backwash water flows. Bottoms may be either cast-iron manifolds, concrete cast-in-place, or precast plates or blocks. Surface agitator or sweeps are very desirable for proper cleaning of the filter media during the washing cycle.

Filter sand should be of the following specifications:

1. Effective size: 0.35 to 0.55 millimeters;
2. Uniformity coefficient: 1.70 or less;
3. Dustcontent: Less than 0.5 percent; and
4. Depth of sand: 24 to 30 inches.

If Anthrafilt is used, the following specifications apply:

1. Effective size: 0.65 to 0.75 millimeters;
2. Uniformity coefficient: 1.7 or less; and
3. Water wash rate: should be adjusted to give 18-inch rise per minute.

Supporting gravel for the filter media should consist of:

1. First 3-inch layer of 5/8- to 1-inch size stone;
2. Second 3-inch layer of 3/8- to 5/8-inch size stone;
3. Third 3-inch layer of 3/16- to 3/8-inch size stone; and
4. Fourth 3-inch layer of number 10 to 3/16-inch stone or Torpedo sand.

To provide for proper expansion of the filter media curing the washing cycle, the minimum distance from the top of the wash through to the top of media should be at least 27 inches. Wash water troughs to the top of the media should be at least 27 inches, and should be of dimensions adequate to carry the maximum wash water rate. The spacing of such troughs should not be greater than 5 to 7 feet

Chemical feed equipment: Chemical feed equipment should be of dependable make and accuracy to provide correct dosages. They should be sufficient in number so that split dosage is unnecessary for any one machine except the chlorinator, which is best operated from a panel and has several points of application. Dry chemical feeders should have capacities ranging from 50 to 100 pounds per million gallons of water treated. The upper limit should be provided for the coagulant feed machines.

Chlorinators and chlorine cylinders should be kept in separate rooms from the other feeders for safety reasons. Leakage of chlorine gas will react with dampened metal surfaces to cause corrosion. The chlorinator room should be provided with an exhaust fan located approximately 6 inches above the floor and with a capacity sufficient for two complete air changes per minute. The fan control should be located outside the chlorinator room. A gas mask also should be stored outside the room.

When fluoride compounds are added to the water, the storage of the fluoride chemicals should be kept separate from other chemical storage so as to eliminate the danger of mixing this chemical with other water treatment chemicals.

2.8 Factors Leading to Water Quality Deterioration

Water storage facilities, after-water treatment, and the pipe network in a community that transports water from the water storage location(s) to supply point of consumption, constitutes a complex network of entrapped water where uncontrolled chemical and biological reactors can produce significant variations in water quality in both time and space. The primary factors of water quality deterioration in distribution systems include the following:

1. contamination via cross-connections or from leaky pipe joints;
2. corrosion of iron pipes and dissolution of lead and copper from pipe walls and joints;
3. loss of disinfectant residual in storage facilities with long resident time (this can also occur from long resident time in water mains where the flow velocity is inadequate to keep all of the water moving);
4. bacterial regrowth and harboring of opportunistic pathogens;
5. supply sources going online and offline;

6. reactions of disinfectants with organic and inorganic compounds resulting in taste and odor problems;
7. increased turbidity caused by particulate resuspension; and
8. new formation of disinfection byproducts, some of which could be suspected carcinogens.

The driving factors affecting water quality in a distribution system:

1. the quality of the treated water fed to the system;
2. the material and condition of the water pipes, distribution system valves, and storage facilities that make up the water system; and
3. the amount of time water is retained in the system.

With reference to the last item, it is most important to understand that on a looped pipe network system, the water reaching any particular consumer is actually a blend of water parcels that may originate from different sources at different points in time and follow different flow paths.

Looped water mains can have an enormous influence on the relation between residence time and water quality. Actions that can be taken to improve water quality or prevent its deterioration in the distribution system include

1. changes in treatment practices;
2. pipe repair;
3. periodic flushing of the water system through fire hydrants;
4. relining or replacing pipes; and
5. modifications to the water supply operation by circulating water in storage.

CHAPTER THREE

METHODOLOGY

Over the past years, many water supply projects were built by different individuals for personal use and sometimes for the community, governmental and non-governmental organizations. At present about Fifty percent (50%) of rural population have access to improved water supply system, therefore to know if the study area has access to improved water supply there following methods area used.

3.1 Data collection methods

A stratified random sampling technique was adopted to select areas for the sample needed for the study. In the second stage household were selected for interview. The sampling methodology was determined from Arkin and Colton (1963) as cited by (Bhandari, 21 2007): the sample size determined the expected rate of occurrence as not less than 90% at 95% confidence level with a precision level of 3%.

$$n = \frac{NZ^2 * p * (1-p)}{Nd^2 + Z^2 * p(1-p)}$$

where n is the sample size, N is the total number of households, Z is the confidence level at 95% of Z = 1.96, P is the estimated population proportion of 0.5 which maximize the sample size and d is the error limit of 5% which is equal to 0.05.. This comprises sample size of 40 respondents randomly selected from the total of 407 beneficiary households with a population of 4362 (2006 Census)

. In the second stage, for the primary data collection the household (especially women who carry out water collection) were interviewed. The instruments of the research were structured and semi structured questionnaires. Essentially cross-sectional primary data was collected from households about their water use practices and water quality perceptions. In addition to that data on socio-economic, water utilization characteristics and household determinants of collecting water from improved water sources were gathered. For the accuracy of the measured values such as distance from the source to the house, time taken to collect water, and locations were taken from the GPS readings by averaging the center of the inhabitants" location to the water source.

3.2 Water Sampling

Water samples were collected from different sources of water that are majoly used by the community. A total of eight water samples were collected for laboratory analysis from which three samples were from well, and another three samples were from bore-hole and two samples from hand-pump .In addition, samples were collected both from improved water sources and unimproved nearby alternative water sources currently used as main sources for household consumptions. However the distance covered between these sources and the houses where the water are been consumed ranged from 40 meters to 450 meters. The samples collected from hand dug wells, Bore-holes and Hand-pump water which were taken to the laboratory for analysis. Based on the water quality of the samples investigated, the status of the existing water quality was compared with the standards of the world health organization (WHO, 2004)

Table 3.0: Water source characterization

S/N	Location of Water Source	Sample Code	Type of Water Source	Protected/ Not Protected (Description of the Water Source)	Distance From soak away (Metres)	GPS Location of Water Sources	
						Latitude	Longitude
1	Adjacent to Ozone's compound	A	Well	Protected	75	7^0 47' 55" N	5^0 29' 58" E
2	Ootunja Central	B	Bore-Hole	Protected	180	7^0 47' 41" N	5^0 29' 55" E
3	Beside ogunsami's house	C	Hand-Pump	Protected	200	7^0 47' 41" N	5^0 29' 52" E
4	Ootunja Bus-stop	D	Bore-Hole	Protected	50	7^0 47' 41" N	5^0 29' 56" E
5	Filani's quarters	E	Well	Protected	Not in range	7^0 47' 58" N	5^0 30' 15" E
6	Ootunja new site	F	Bore-Hole	Protected	100	7^0 47' 41" N	5^0 29' 52" E
7	Ootunja	G	Hand-Pump	Protected	Not in range	7^0 47' 46" N	5^0 29' 52" E
8	Ogu's compound	H	Well	Protected	150	7^0 47' 56" N	5^0 29' 58" E

3.3 Method of analysis of Samples

Water quality analysis was used to present the household perception of water quality following the results of the laboratory tests as compared with the WHO standards. Questionnaires were used to obtain information basically from females who took the greater responsibility of water collection and asked about the consumed water quality perceptions on color; taste and odor during data collection employed. For the analysis of water quality the main water quality indicator parameters were detected from the laboratory including physicochemical and bacteriological quality. The physicochemical parameters included: electrical conductivity (EC), PH, Physical Parameters. Total Dissolved Solids (TDS), turbidity, Chemical Parameters nitrate, nitrite, iron, manganese and residual chlorine. Turbidity, an important indicator of water quality as it can protect bacteria and viruses from disinfection, is also a good vector for the introduction of Giardia and Cryptosporidium cysts in drinking water system (Ando, 2005). In addition, bacteriological parameters including total coliforms and fecal coliforms were analyzed using filter membrane technique by incubating the membrane on a growth promoting medium for 24 hrs at $37^{\circ}C$ and $44.5^{\circ}C$, respectively, and counting the resultant colonies per 100ml of samples collected from sources.

3.3.1 Temperature In an established system the water temperature controls the rate of all chemical reactions. It is obtained using the thermometer.

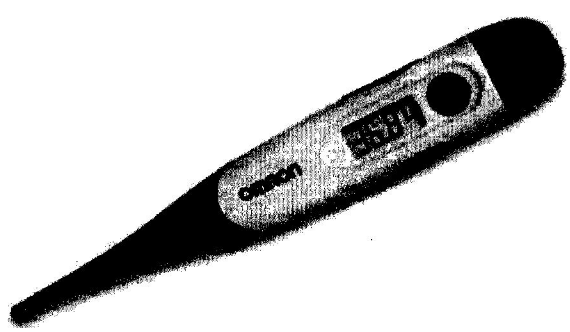

Plate 01: Thermometer

3.3.2 pH is most important in determining the corrosive nature of water. Lower the pH value higher is the corrosive nature of water. pH was positively correlated with electrical conductance and total alkalinity(Guptaa 2009). The reduced rate of photosynthetic activity the assimilation of carbon dioxide and bicarbonates which are ultimately responsible for increase in pH, the low oxygen values coincided with high temperature during the summer month. Various factors bring about changes the pH of water. The higher pH values observed suggests that carbon dioxide, carbonate-bicarbonate equilibrium is affected more due to change in physicochemical condition (Karanth 1987).

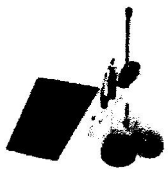

Plate2: pH Meter

3.3.3 EC (Electrical Conductivity): Conductivity shows significant correlation with ten parameters such as temperature , pH value , alkalinity , total hardness , calcium , total solids, total dissolved solids , chemical oxygen demand , chloride and iron concentration of water. Navneet Kumar et al (2010) suggested that the underground drinking water quality of study area can be checked effectively by controlling conductivity of water and this may also be applied to water quality management of other study areas. It is measured with the help of EC meter which measures the resistance offered by the water between two platinized electrodes. The instrument is standardized with known values of conductance observed with standard KCl solution.

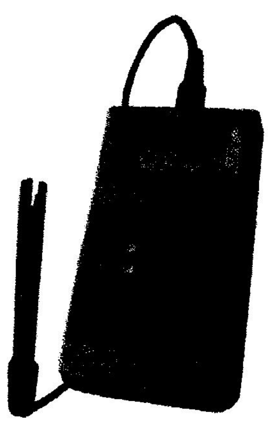

Plate 3: EC Meter

3.3.4 Alkalinity It is composed primarily of carbonate and bicarbonate, alkalinity acts as a stabilizer for pH. Alkalinity, pH and hardness affect the toxicity of many substances in the water. It is determined by simple dil HCl titration in presence of phenolphthalein and methyl orange indicators. Alkalinity in boiler water essentially results from the presence of hydroxyl and carbonate ions. Hydroxyl alkalinity (causticity) in boiler water is necessary to protect the boiler against corrosion. Too high a causticity causes other operating problems, such as foaming. Excessively high causticity levels can result in a type of caustic attack of the boiler called "embrittlement".

3.3.5 Calcium: It is measured by complexometric titration with standard solution of ETDA using Patton's and Reeder's indicator under the pH conditions of more than 12.0. These conditions are achieved by adding a fixed volume of 4N Sodium Hydroxide. The volume of titre (EDTA solution) against the known volume of sample gives the concentration of calcium in the sample.

3.3.6 Magnesium It is also measured by complexometric titration with standard solution of EDTA using Eriochrome black T as indicator under the buffer conditions of pH 10.0. The buffer solution is made from Ammonium Chloride and Ammonium Hydroxide. The solution resists the pH variations during titration.

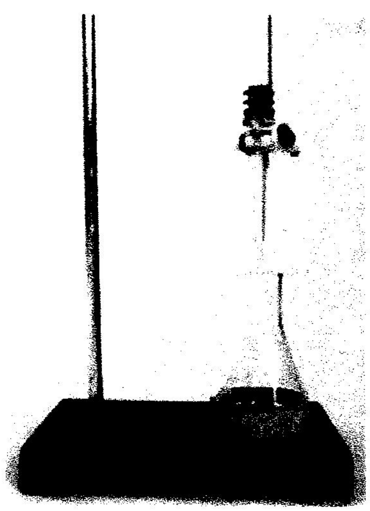

Plate 4: Titration set-up

3.3.7 Chloride It is measured by titrating a known volume of sample with standardized silver nitrate solution using potassium chromate solution in water or eosin/fluorescein solution in alcohol as indicator. The latter indicator is an adsorption indicator while the former makes a red colored compound with silver as soon as the chlorides are precipitated from solution.

3.3.8 Turbidity: Turbidity is a measure of the "cloudiness" of the water. Sediment, algae, bacteria and zooplankton all contribute to what is technically known as the Total Suspended Solids (TSS) that increase the turbidity. As turbidity increases, the degree to which sunlight penetrates the water column declines. This obviously has an impact on photosynthetic rates in algae and submerged vegetation. High turbidity can also raise surface water temperature as suspended particles near the surface absorb more heat from sunlight. Suspended soil particles may also carry nutrients, pesticides and other pollutants and they can bury benthic organisms. Turbid waters tend to be low in dissolved oxygen. Turbidity can be measured with a turbidity meter in formazine turbidity units (FTU's).

3.3.9 Phosphate: Phosphorus (P) usually occurs in natural systems as phosphate (PO_4^{-3}). This phosphate may be bound to organic compounds (organic phosphate) or inorganic compounds (inorganic phosphate or orthophosphate). Inorganic phosphate is the form most readily available to plants and therefore is generally of greater interest than organic phosphate. Phosphorus tends to be less abundant than nitrates in freshwater ecosystems and is, therefore, often a limiting factor for plant and algal growth. The addition of phosphorus (in the form of phosphates) commonly results in algal blooms (cultural eutrophication). Phosphates (inorganic phosphates only) can be measured with an ion-specific meter.

3.3.10 Nitrate: Nitrogen appears in several forms in water sources, including nitrate (NO_3), nitrite (NO_2) and ammonia (NH_3). Of these, nitrates are probably the most common inorganic pollutant tested in water. Nitrates can be measured with an ion-specific meter.

3.3.11 Total hardness: Total hardness is defined as the sum of the calcium and magnesium concentration, both expressed as $CaCO_3$, in mg/L. Hardness is determined by the EDTA method in alkaline condition; EDTA and its sodium salts from a soluble chelated complex with certain metal ions.

3.3.12 Residual chlorine: The iodometric method is used for measuring total chlorine concentrations greater than 1 mg/L. All acidic iodometric methods suffer from interferences, generally in proportion to the quantity of potassium iodine (Kl) and H+ added.

3.3.13 Total solid: Residue left after the evaporation and subsequent drying in oven at specific temperature 103-105°C of a known volume of sample are total solids. Total solids include "Total suspected solids" (TSS) and "Total dissolved solids" (TDS). Whereas loss in weight on ignition of the same sample at 500°C, 50°C, in which organic matter is converted to CO_2 volatilization of inorganic matter as much as consistent with complete oxidation of organic matter, are volatile solids

3.3.14 Nitrate (NO_3) : Determination of nitrate (NO_3) is difficult because of the relatively complex procedures required, the high probability that interfering constituents will be present and the limited concentration ranges of the various techniques. Nitrate is the most highly oxidized form of nitrogen compounds commonly present in natural waters. UV spectrophotometer method is used in determining the presence of Nitrate (NO_3).

3.3.15 Aluminum (Al): Aluminum is the third most abundant element on the earth's crust. The presence of aluminum in all natural water is in the form of soluble salt, a colloid, or an insoluble compound. Soluble, colloidal, and insoluble aluminum may be present in treated water in residual form of coagulation with aluminum-containing material. Eriochrome-cyanine method is used for determining aluminum in water.

3.3.16 Zinc (Zn): Zinc is an essential and beneficial element for human growth. Concentration above 5mg/L can cause a bitter astringent taste in water. The zinc concentration in water varies from 0.06 to 7.0 mg/L with a mean concentration of 1.33 mg/L. Zinc most commonly enters the domestic water supply from deterioration of galvanized iron and dezincification of brass. The method used is inductively coupled plasma method.

CHAPTER FOUR
RESULT AND DISCUSSION

4.1 Distributions of Respondents by Access to Safe/Improved Water for Domestic Use

Table 4.1 presents results obtained the analysis of questionnaire administered to 40 respndentsin Otunja community, Ikole Local Government Area, Ekiti state.

TABLE 4.1: TYPE OF WATER SOURCE, WATER USE AND FUNCTIONALITY OF GROUND WATER SOURCES SURVEYED IN OTUNJA COMMUNITY

	Number of Respondents	PERCENTAGE (%)
COMMUNITY		
Otunja	40	100.0
TOTAL	**40**	**100.0**
SEX		
Male	17	42.5
Female	23	57.5
TOTAL	**40**	**100.0**
TYPE OF WATER SOURCE		
Well	18	45.0
Hand pump	11	27.5
Borehole	11	27.5
TOTAL	**40**	**100.0**
DOMESTIC USE OF WATER: WASHING		
Yes	40	100.0
No	-	-
TOTAL	**40**	**100.0**
DOMESTIC USE OF WATER: COOKING		
Yes	40	100.0
No	-	-
TOTAL	**40**	**100.0**
DOMESTIC USE OF WATER: BATHING		
Yes	40	100.0
No	-	-
TOTAL	**40**	**100.0**
WATER SOURCE FUNCTIONAL		
Yes	40	100.00
No	-	-
TOTAL	**40**	**100.00**

WATER AVAILABILITY		
Seasonal	-	-
Perennial	40	100.0
TOTAL	**40**	**100.0**
MAIN SOURCE OF WATER		
Borehole	11	27.5
Handpump	12	30.0
Protected Hand dug well	17	42.5
TOTAL	**40**	**100.0**
DISTANCE(MINUTES)		
Below 30minutes	40	100.0
31-60minutes	-	-
TOTAL	**40**	**100.0**
CONTAINER		
Bucket	22	55.0
Jeri can	18	45.0
TOTAL	**40**	**100.0**
NUMBER OF TIMES		
Once	-	-
Twice	9	22.5
Thrice	21	52.5
More than three times	10	25.5
TOTAL	**40**	**100.0**
ADEQUACY		
Yes	38	95.5
No	2	5.0
TOTAL	**40**	**100.0**
SMELL		
NO Smell	40	100.0
Foul Smell	-	-
TOTAL	**40.0**	**100.0**
TASTE		
Yes	7	17.5
No	33	82.5
TOTAL	**40**	**100.0**
LOOK		
Clear	35	87.5
Cloudy/dirty	5	12.5
	40	**100.0**

SOURCE: FIELDWORK 2016

A random sampling of 40 respondents were selected for this study, out of which 57.5%were females and42.5% were males.45.0% revealed that they derive their water from the well, 27.5% borehole and another 27.5% hand-pump. The percentage distribution according to domestic use of water shows that the water is safe. As all the respondents revealed that, they use the water gotten from their water source for cooking, bathing and washing and the water is functional and always available (perennial).

Majority (42.5%) of the respondents' main source of is from a protected hand dug well while 27.5% and 30.0% of the respondents main source of water is borehole and hand pump respectively. Also, it takes less than 30minutes walk from all the respondents' home to their water source, revealing that is close and they have access to the water. 55.5% uses bucket to fetch their water, while 45.5% uses Plastic containers and it takes 22.5% of the respondents ,twice, to fetch their satisfied water, 52.5% fetches thrice and 25.5% more than three times. 95% of the respondents revealed that the water is adequate while 5% said it's not. All the respondents revealed that the water do not smell, but in terms of taste of water, 82.5% revealed that the water do not have taste and 17.5% said the opposite (it has taste). More so, 87.5% of the study population revealed that water is clear and 12.5% said it's cloudy/dirty.

4.2 Household Water Consumption

. Water collection material was the most important component for those involved in fetching of water from the various water sources, it was found that buckets and Jeri cans were the two most common types of materials. Thus in area about 45% used Jeri can and those that used bucket were about 55% from those interviewed.

The frequency of water collection from the water sources on average was 3.2 times based on those interviewed. Access to water supply using distance cover, time taken and queuing time were discussed below. Based on that, the average maximum distance covered from the various sources were less than 250 meter, its takes an individual about 15 minutes to fetch water including queuing time making it 5.25 hours spent in total per week per person.

4.3 Water quality:

Consumers concerning their drinking water said aesthetic factors such as taste, odor, and color were very important. Likewise the drinking water trustworthiness depends on the perception of consumers and the resultant complaints due to tastes, odors, color or any other particulate matter

4.3.1 Aesthetic Parameters

All the water samples taken from sources were tested for physical, chemical and microbiological qualities of the water sources. From the total water samples analyzed for appearance, only one water sample source was not clear and that was sample A which is a hand-dug well all the other water sources was clear. From the test on odour and taste 12.5% of the total sample shows that odour and taste was present, this was detected in sample A. The result is shown below in table 4.2 while fig 4.1 shows the comparison of the result with the WHO standard for physical parameters.

Table 4.2: Physical Parameter

PHYSICAL PARAMETER		RESULTS OF SAMPLES								
S/N	PARAMETER	A	B	C	D	E	F	G	H	WHO standards
1	TEMP (^{0}C)	29	25	30	30	30	30	30	30	22-30
2	APPEARANCE	Brownish	Clear	Clear	Clear	Clear	Clear	Clear	Clear	CLEAR/COLOURLESS
3	COLOUR(Hazen)	18.00	7.00	7.00	8.00	8.00	6.0	5.00	6.00	0-15
4	TASTE	Present	None	None	None	None	None	None	None	Unobjectionable
5	ODOUR (TON)	Present	None	None	None	None	None	None	None	Unobjectionable

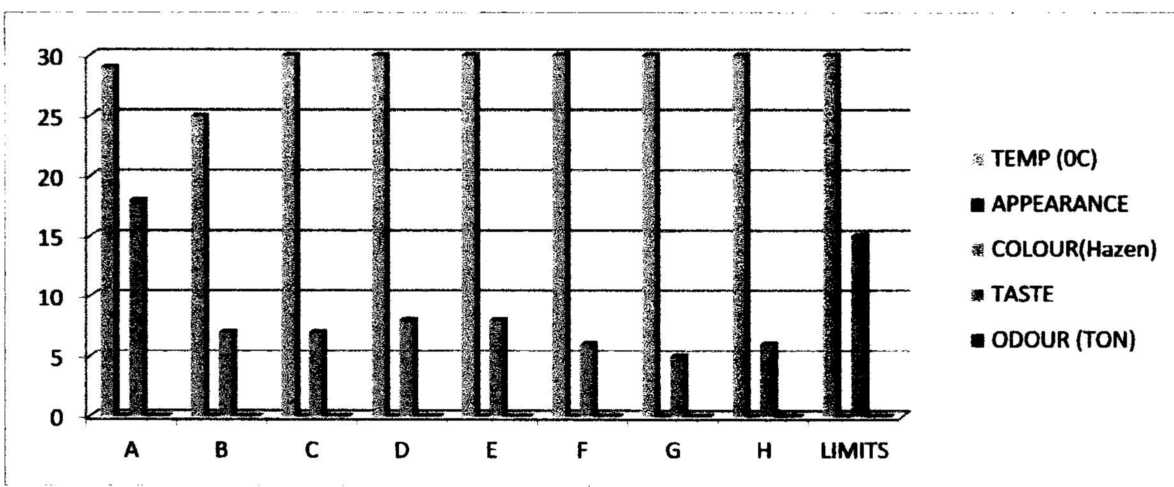

Fig 4.1: Chart comparing the Physical parameters with the Limit

For test on turbidity, 12.5% of the samples also didn't meet the W.H.O requirement while the remaining 87.5% met the recommended value of WHO that is 5 NTU in the rural area. For 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 251.4 ohms/cm. The pH value for all the water samples was within the range of W.H.O standard of (6.5-8.5) on average the pH value obtained was 6.7. For test on total solid, 25% of the total solid didn't meet the requirement W.H.O standard and on average the total solid was 351mg/L. Residual Chlorine was not detected from all the water samples that was analyzed. Total alkalinity $CaCo_3$ on average was 45mg/L, all falls within the permissible value of W.H.O standard of (100mg/L). Total hardness $CaCo_3$ on average was 65mg/L. Metals such as Iron, Zinc, Aluminum, Calcium, Magnesium, Lead, Sulphate So_4^3 and Manganese Mn which is the main source of displeasing test and consumes much detergent when used for washing, were all detect but they all fall within the permissible value of W.H.O standard. Nitrate (NO_2) was not detected in 87.5% of the water samples analyzed. It was proved that test of water is the main indicator of aesthetic water quality status (Dietrich, 2006). The result is shown below in table 4.3 while fig 4.2 shows the comparison of the result with the WHO standard for chemical parameters.

Table 4.3: Chemical Parameter

S/N	PARAMETER	A	B	C	D	E	F	G	H	LIMITS
		RESULTS OF SAMPLES								
1	Turbidity (NTU)	10.18	10.18	4.18	4.18	4.80	4.80	4.10	4.20	5.00
2	Conductivity	380.5	380.5	240.0	280.0	140.0	240.0	140.0	210.0	1000
3	pH	6.60	6.50	6.80	6.50	6.70	6.50	6.70	6.80	6.5-8.5
4	Total Solid mg/L	725.00	154.0	502.0	198.0	138.0	395.0	398.0	482.0	500
5	Residual Chlorine	ND	ND	ND	ND	ND	ND	ND	ND	0.2-0.5
6	Total Alkalinity	62.60	42.6	48.6	58.8	42.6	48.0	48.6	34.2	100
7	Total Hardness	75.00	65.0	55.0	52.0	58.6	56.2	54.2	52.6	100
8	Iron mg/L	1.88	0.08	0.05	0.20	0.10	0.10	0.12	0.10	0-0.3
9	Zinc	3.20	2.40	1.70	2.80	2.20	2.50	3.20	2.60	5.00
10	Aluminum	0.00	0.00	0.00	0.00	0.08	0.00	0.20	0.10	0-5.0
11	Calcium	45.00	60.0	53.0	42.0	54.0	32.0	38.9	62.4	75.00
12	Magnesium	15.50	17.2	9.20	35.2	18.4	25.2	20.8	13.6	20
13	Lead	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
14	Chlorine Cl	72.0	23.8	27.5	28.8	24.2	18.5	12.5	42.80	100
15	Nitrate (NO_2)	2.24	0.01	ND	ND	ND	ND	ND	ND	0.02
16	Nitrate (NO_3)	12.80	6.80	3.80	3.80	2.80	2.20	2.80	5.80	10.00
17	Organic Matter	2.62	0.62	23.4	4.62	2.25	5.62	3.42	10.25	30.00
18	Silica	14.00	8.00	10.0	12.0	8.00	10.0	8.00	8.00	30.00
19	Sulphate mg/L	85.00	55.0	45.0	35.0	24.0	22.1	25.8	25.00	100
20	Manganese	0.20	0.03	0.00	0.03	0.02	0.02	0.02	0.02	0.05

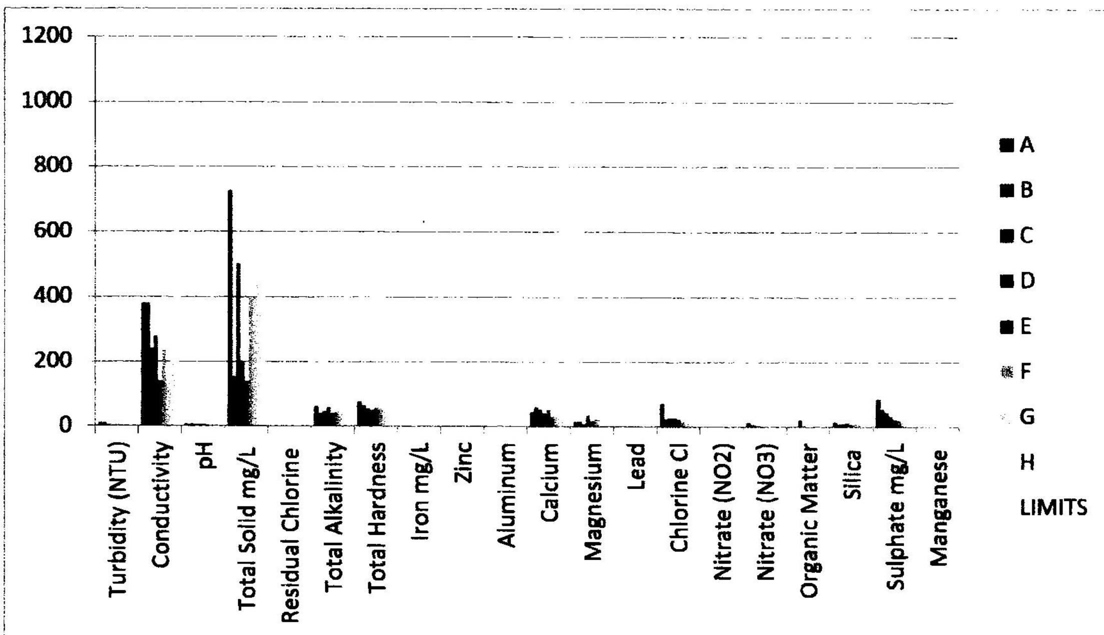

Fig 4.2:Chart comparing the Chemical parameters with the Limit

4.3.2 Micro-Biological parameters

Table 4.4: Micro-Biological parameters

		RESULTS OF SAMPLES								
S/N	PARAMETER	A	B	C	D	E	F	G	H	LIMITS
1	AerobicMesophilic(cfu/ml)	T.N.T.C	T.N.T.C	$6x10^3$	T.N.T.C	$2x10^3$	$7x10^3$	$5x10^3$	$4 x 10^3$	10^3
2	Total coliform organism (cfu/ml)	12	8	4	4	2	10	2	8	0

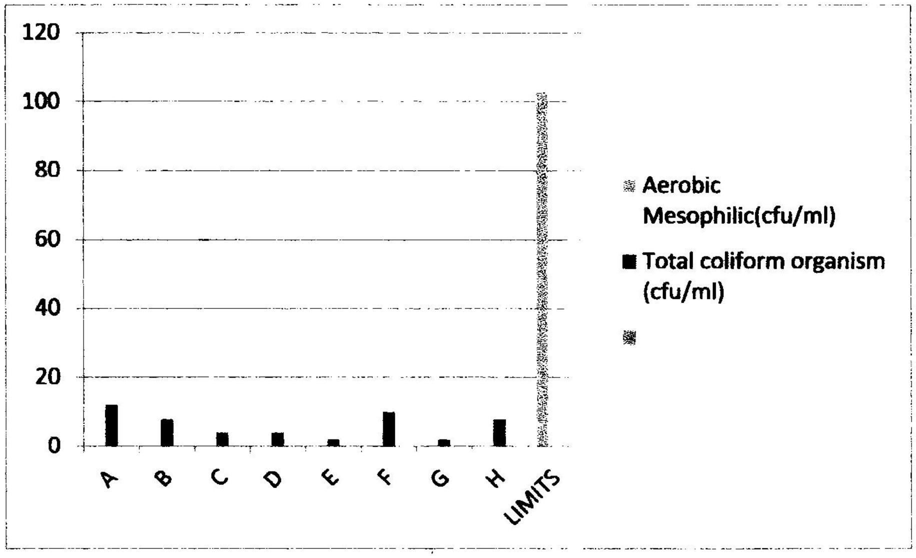

Fig 4.3: Chart comparing the Micro-Biological parameters with the Limit

The water samples were all contaminated with Aerobic mesophilic organism and coli form organism. The results of the test exceed the standard for W.H.O for both micro biological parameters. In samples A,B,D aerobic mesophilic organism were too numerous to count The result is shown below in table 4.4 while fig 4.3 shows the comparison of the result with the WHO standard for physical parameters.

4.4 The Discrepancy between Actual and Reported Access to Improved Water Sources

Accessibility of water supply points principally supplying adequate and quality water for the wellbeing of human health. Sustainable Access to improved and safe drinking water is one of the MDGs goals. Whereas the level of determining whether the community got access to improved and safe water for domestic use was difficult to know the exact value. Such disparities came from the absence of real data and the response of the respondents during the field interview. All respondents (100%) claimed to have acess to clear water, tasteless water supply and odourless water supply from their various water sources, but the result from the laboratory shows a different result for appearance (colour) about 12.5% of the water sample was brownish, for odour, only 87.5% of the water samples were odourless same as the taste of the water samples. This probably happened because the respondents were scared of giving the real conditions of their water sources.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the research work, the following conclusions are made: All samples meet the meet the required drinking standard values except for sample A in which the Iron, Nitrate and Manganese content of the chemical parameters are above the required values. Sample A also did not meet the drinking water standard for most of the physical parameters such as odour and taste and colour, odour and taste was present was present while the colour of the water brownish. Also all the water sample did not meet the micro-biological W.H.O standard. The water samples were all contaminated with Aerobic mesophilic organism and coli form organism, Laboratory results shows that sample A,B,D aerobic mesophilic organism were too numerous to count.

The use of plastic container which is bucket and Jeri cans which reduces the heavy load and contamination are the major collection water materials.

There is a positive relationship between collection time, distance, quantity and quality of water from sources domestic use for individual household when compared with the W.H.O standard of 60L/cap/day and water sources distances on average is between 200-250metres.

5.2 Recommendations

After this study has being carried out the following will help in providing a more access to improved water supply for domestic used in the community :

1. Government should supplement the provision of drinking water rather than creating competition between households with more water consuming activities such as areas around the palace with underlaid rock which prevent individuals from sinking bore-holes and hand-dug wells.
2. NGOs / funding agencies should participate in development of improved water supply programmes
3. A lot of awareness creation activities should be done on sanitation and hygiene through extension workers.

4. Continuous follow up on already installed schemes will give a better chance to sustain the water schemes.
5. The community should treat their drinking water before consumption

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Appendix 1

<table>
<tr><td rowspan="2">Name of community:..................................

Local Area:

....

State:

....

Date:

....

Population:

....</td><td colspan="2">Name of Respondent:

....

Age of Respondent..................................</td></tr>
<tr><td>Longitude :</td><td>Latitude :</td></tr>
</table>

1. Name of water source: ....
2. What is the water used for (a) washing (b) cooking (c) bathing (d) cocking
3. Is the water source functional (a) Yes (b) Only during rainy season (c) No
4. Which of the following source of water is your main source of water (a) Bore well/hand pump (b) Community well (c) household water supply (piped) (d) Stream
5. How far (in meters) is the source of water to your home (a) about 100m (b) 200 – 400m (c) more than 500m

6. How long (in minute) does it take to fetch water and return home? (a) below 30min (b) 31 – 60min
7. Which container do you use in fetching water (a) bucket (b) Jerry can
8. How many times do you fetch water in a day with the container (a) once (b) twice (c) 3 times
9. Is the quantity of water from your main source adequate (a) Yes (b) No
10. How does the water smell (a) No smell (b) Foul Smell
11. Does the water have taste (a) yes (b) No
12. What does the water look like? (a) Clear (b) cloudy / Dirty

Interview Complete