HAZARD ANALYSIS OF DOMESTIC WATER SELF SUPPLY FROM HAND-DUG WELL IN ASIN COMMUNITY OF IKOLE LOCAL GOVERNMENT AREA

By

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ABSTRACT

Domestic water supply is a daily necessity and key factor in human health and well-being. Without water, life cannot be sustained and lack of access to adequate water supplies leads to wide spread of diseases with children bearing the greatest health burden associated with poor water quality and sanitation. Drinking water is water that is of sufficiently high quality so that it can be consumed or used without risk of immediate or long term harm. Asin-Ekiti community is situated in Ikole-ekiti, Ekiti, Nigeria. It is located in south-western Nigeria on longitude7° 47′ 0″ North and latitude 5° 31′ 0″ East. The predominant mother tongue spoken in Asin-ekiti of Ikole, Ekiti State is Yoruba. It has an area of 321 $km^2$and a population of 168,436 at the 2006 census. Asin-Ekiti of Ikole Local Government Area is situated in the deciduous forest area of the State. This research work focused on hazard analysis of domestic water self-supply from hand-dug well in Asin-Ekiti community of Ikole LGA. Also, the water sources under study in Asin-Ekiti community were located and samples were randomly collected from twenty hand-dug well with adequate precaution from each of the sources and tested for the physical, chemical and bacteriological parameters thereby monitoring the water quality of the samples. Results afterward showed that not all water samples collected met the standards for drinking water. All Physical parameters met the recommended standard but for the chemical parameters, the pHof samples 1,2,3,4,5,10,15 and 16 were slightly below recommended standard while Magnesium content of all samples were above NSDWQ recommended limit but within WHO recommended limit. The Total Coliform count of Sample 1,2 and 3 were within recommended limit but all the remaining samples were above recommended limit which show evidence of contamination with moderate risk and can be decontaminated by chlorination. Results from the Hazard Analysis showed that three water sources monitored met all the requirements for drinking water quality, corrective measured were proffered and no flooding around all water source. It is recommended that regular monitoring of domestic water quality should be maintained for all the domestic water sources.

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My profound gratitude goes to Almighty Allah the beneficent and the merciful, all praise and adoration belongs to Him who made my existence a possibility and has so far been in the control of my life and also promises to be in control forever.

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DEDICATION

This project is dedicated to Almighty Allah for being a source of knowledge and inspiration.

CERTIFICATION

This is to certify that this project was prepared by Zakariyyah, AbdulazeezTaiwo (CVE/12/0835) under my supervision, in partial fulfillment of the requirements for the award of a Bachelor of Engineering (B.Eng) degree in Civil Engineering, Federal University Oye Ekiti. Ekiti State Nigeria.

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LIST OF ABBREVIATIONS

BOD	Biochemical Oxygen Demand
NSDWQ	Nigerian Standard for Drinking Water Quality
PH	Potential of Hydrogen
TDS	Total Dissolve Solid
UNICEF	United Nations International Children's Emergency Fund
WHO	World Health Organisation
USEPA	United States Environmental Protection Agency

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CHAPTER ONE

1.0 INTRODUCTION

Domestic water supplies are one of the fundamental requirements for human life. Without water, life cannot be sustained beyond a few days and the lack of access to adequate water supplies leads to the spread of disease. Children bear the greatest health burden associated with poor water and sanitation. Diarrhoeal diseases attributed to poor water supply, sanitation and hygiene account for 1.73 million deaths each year and contribute over 54 million Disability Adjusted Life Years, a total equivalent to 3.7% of the global burden of disease (WHO, 2002).

This places diarrhoeal disease due to unsafe water, sanitation and hygiene as the 6th highest burden of disease on a global scale, a health burden that is largely preventable (WHO, 2002).

Other diseases are related to poor water, sanitation and hygiene such as trachoma, schistosomiasis, ascariasis, trichuriasis, hookworm disease, malaria and Japanese encephalitis and contribute to an additional burden of disease. As of 2000 it was estimated that one-sixth of humanity (1.1 billion people) lacked access to any form of improved water supply within 1 kilometre of their home (WHO and UNICEF, 2000).

Lack of access to safe and adequate water supplies contributes to ongoing poverty both through the economic costs of poor health and in the high proportion of household expenditure on water supplies in many poor communities, arising from the need to purchase water and/or time and energy expended in collection.

Pure water does not generally occur in nature. This is because all natural water whether surface, precipitation or ground all contain dissolved solids and gases as well as suspended matter. The quality and quantity of these constituents depends on geologic and environmental factors, which continuously change as a result of the reaction of water with contact media and human activities. These activities especially human can adversely affect the groundwater resources. Ground water is polluted by runoff from fertilized fields, livestock areas, abandoned mines, salted roads and industrial areas. Other sources of groundwater pollution include leachate from refuse dumps, gasoline leakage into ground water from underground storage tanks, waste water disposal systems. The effect of these pollutants in water can give rise to life threatening diseases especially diseases associated with unimproved domestic water supply, these diseases are water borne, water washed, water related insect vector etc.

The use of unimproved drinking water sources is a major challenge coupled with uncontrolled siting of latrines. Sanitation facilities which are appropriate to meet the needs and demands of communities at affordable cost both at construction and operation and maintenance for end users are viable options to the control of contamination of domestic water sources. Factors such as the presence of uncapped wells and poor sanitary completion of the wells are as important as subsurface leaching of microbial contamination.

1.1 Aim

To conduct a comprehensive sanitary, water quality and water quantity analysis from twenty selected hand-dug wells in Asin community of Ikole L.G.A

1.2 Objectives

- To determine the water quality parameters from selected sources
- To determine the quantity of water consumed per capita per day
- To carried out sanitary analysis around each water source

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Domestic Water Supply

In its Guidelines for Drinking-Water Quality, World Health Organization (WHO) defines domestic water as being 'water used for all usual domestic purposes including consumption, bathing and food preparation' (WHO, 1993). This implies that the requirements with regard to the adequacy of water apply across all these uses and not solely in relation to consumption of water. Although this broad definition provides an overall framework for domestic water usage in the context of quality requirements, it is less useful when considering quantities required for domestic supply.

Sub-dividing uses of domestic water is useful in understanding minimum quantities of domestic water required and to inform management options. In the 'Drawers of Water' study on water use patterns in East Africa, White et al. (1972) suggested that three types of use could be defined in relation to normal domestic supply:

1. Consumption (drinking and cooking)
2. Hygiene (including basic needs for personal and domestic cleanliness)
3. Amenity use (for instance car washing, lawn watering).

In updating the Drawers of Water study, Thompson et al. (2001) suggest a fourth category can be included of 'productive use' which was of particular relevance to poor households in developing countries. Productive use of water includes uses such as brewing, animal watering, construction and small-scale horticulture.

The first two categories identified by White et al. (1972): 'consumption' and 'hygiene', have direct consequences for health both in relation to physiological needs and in the control of diverse infectious and non-infectious water-related disease. The third category: 'amenity' may not directly affect health in many circumstances. Productive water may be critical among the urban poor in sustaining livelihoods and avoiding poverty and therefore has considerable indirect influence on human health.

2.1.1 Consumption

Water is a basic nutrient of the human body and is critical to human life. It supports the digestion of food, adsorption, transportation and use of nutrients and the elimination of toxins and wastes from the body (Kleiner, 1999). Water is also essential for the preparation of foodstuffs and requirements for food preparation are included in the discussion of consumption requirements.

2.1.1.1 Basic Hydration Requirements

The human body requires a minimum intake of water in order to be able to sustain life before mild and then severe dehydration occurs. Adverse health effects have been noted from both mild and severe dehydration and the latter can be fatal.

The US National Institutes of Health (2002) provide a definition of mild dehydration as being a loss of 3-5% of body weight, moderate dehydration as being 6-10% loss of body weight and severe dehydration (classed as a medical emergency) 9-15% loss of body weight. In a recent review Kleiner (1999) defined mild dehydration as being the equivalent of 1-2% loss of body weight through fluid losses and over 2% loss as severe dehydration, whilst noting that there is no universally applied index of hydration status. Mild dehydration can be reversed by increased fluid intake and this may be enhanced through the use of salt replacement solutions. Severe dehydration will require rehydration strategies involving more than simple fluid replacement, and often food or other osmolar intake is needed; the process may take up to 24 hours (Kleiner, 1999).

2.1.1.2 Quality of Water for Consumption

The quality of water that consumed is well-recognized as an important transmission route for infectious diarrheal and other diseases (WHO, 1993). The importance of water quality continues to be emphasized by its role in epidemics and contribution to endemic disease from pathogens (Ford, 1999; Payment and Hunter, 2001). This affects both developed and developing countries, although the majority of the health burden is carried by children in developing countries (Prüss et al., 2002). However, recent outbreaks such as that of cryptosporidiosis in Milwaukee and E.coli O157:H7 and Campylobacter jejuni in Walkerton, Ontario illustrate that the developed world also remains at risk (Mackenzie et al., 1994).

Disease may also result from consumption of water containing toxic levels of chemicals. The health burden is most significant for two chemicals: arsenic and fluoride. Arsenic contamination of drinking water sources is being found in increasing numbers of water supplies world-wide and in Asia in particular. The total disease burden is as yet unknown, but in Bangladesh, the country with the most widely reported problem, between 35 and 77 million people are at potential risk (Smith et al., 2000). Fluoride is also a significant global problem and WHO (1999) suggest that over 60 million people are affected by fluorosis in India and China and suggest the total global population affected as being 70 million. Nitrate is also of concern although there remains uncertainty about the scale of adverse health effects from nitrate as few countries include methemaglobinaemia as a notifiable disease (Saywell, 1999).

Water provided for direct consumption and ingestion via food should be of a quality that does not represent a significant risk to human health. A 'zero-risk' scenario for public supplies is not achievable and evidence points to the need to define tolerable risks, commonly based on estimates of numbers of excess cases per defined population size. This approach underpins much risk assessment thinking within the water sector for both microbial and chemical contaminants (Fewtrell and Bartram, 2001; Haas et al., 1999; WHO, 1996).

2.2.0 Quantities of Water Required for Cooking

Water is essential as a medium for preparing food. One study noted that the volume of cooking water available may be an important determinant for diarrhea incidence in children over 3 years of age, although this was less important than water quality for the under 3 years age group (Herbert, 1985).

Defining the requirements for water for cooking is difficult, as this depends on the diet and the role of water in food preparation. However, most cultures have a staple foodstuff, which is usually some form of carbohydrate-rich vegetable or cereal. A minimum requirement for water supplies would therefore also include sufficient water to be able to prepare an adequate quantity of the staple food for the average family to provide nutritional benefit.

It is difficult to be precise about volumes required to prepare staples as this depends on the staple itself. However, an example can be provided for rice, which probably represents the most widely used staple food worldwide. Recommendations for nutrition usually deal with the intake of nutrients rather than specific food stuffs. Most food pyramids give a suggest an intake for cereals of 6 to 11 servings per day, or 600 – 1100 grams per day. To prepare rice using the adsorption method (i.e. only sufficient water to cook the rice is added), 1.6 litres is required for 600g per capita per day. More water may be required to ensure that other foodstuffs can be cooked, although defining minimum quantities is difficult as this depends on the nature of the food being prepared. Taking into account drinking needs, this suggests that between 1.5 and 2 litres per capita per day is used for cooking.

2.2.1 Water Quantity Requirements for Hygiene

The need for domestic water supplies for basic health protection exceeds the minimum required for consumption (drinking and cooking). Additional volumes are required for maintaining food and personal hygiene through hand and food washing, bathing and laundry. 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 diarrheal 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. 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 maximize benefits from limited resources (a critical factor both for governments and their populations). It is also 10 driven by the desire to ensure that populations benefit from the interventions that deliver the greatest improvement in their health.

2.3 The Links Between Water Supply, Hygiene and Disease

Classifying diseases by causative agent such as microbe type for infectious disease has a value in terms of understanding etiology of infection. However, a more effective way to inform decision-making is to categorize pathogens /diseases in relation to the broad mode of transmission.

According to Bradley (1977), he suggested that there are four principal categories that relate to water and which are not mutually exclusive:

1. water-borne - caused through consumption of contaminated water (for instance diarrhoeal diseases, infectious hepatitis, typhoid, guinea worm);
2. water-washed - caused through the use of inadequate volumes for personal hygiene (for instance diarrhoeal disease, infectious hepatitis, typhoid, trachoma, skin and eye infections);
3. water-based - where an intermediate aquatic host is required (for instance guinea worm, schistosomiasis);
4. water-related vector - spread through insect vectors associated with water (for instance malaria, dengue fever).

Other workers have suggested a change in this classification system to replace the waterborne category with faecal-oral (to reflect multiple routes of transmission) and to restrict the water-washed diseases to only as those skin and eye infections that solely relate to the quantity of water used for hygiene (Cairncross and Feachem, 1993).

The original Bradley (1977) system has particular value as its focus is on the potential impact of different interventions. The occurrence of particular diseases in more than one group is a legitimate outcome where distinct interventions may contribute to control. Thus guinea worm for example is classified as both a water-based disease and water-borne disease.

2.4 Water Quality

The objective of a community water distribution system that provides drinking water is to deliver sufficient quantities of water where and when it is needed at an acceptable level of quality (the desired chemical and physical characteristics of the water). For the water to be high quality;

i. It must first be free of all harmful bacteria or the index organisms (which will indicate that pathogenic bacteria may find their way into the water supply).
ii. It must be free of objectionable taste and odors that may be caused by either undesirable chemicals or organisms.
iii. It follows that drinking water must be low in concentrations of troublesome minerals, such as iron, sulphur, manganese, calcium, magnesium, and other agents that will make the water unsuitable for use by excessive discoloration or hardness, or non-potable from the standpoint of high chemical content.
iv. The water must be non-corrosive so that it will not react with plumbing fixtures or pipelines to cause failure of such lines, necessitating frequent replacement, or cause the staining of plumbing fixtures.

The quality of water provided by a municipal water system is based on three distinct characteristics, each of which may independently govern the desirable portability of the water. These characteristics are;

1. **Physical quality of water:** The physical quality of water is the appearance of the water to the consumer. Physical quality includes the clearness of the water, taste, odor, and temperature. For water to be of attractive physical quality, it must be clear in appearance, or have low turbidity (less than 5.0 units of turbidity).

i. **Colour:** The colour of the water must be low in concentration so as not to distract the consumer's attention. Colour should be less than 15.0 units of color. The water should be free of substances that may produce taste and odors upon the addition of chlorine, or upon use of water for cooking purposes. It also should be free of trouble-producing organisms such as aromatic oils of algae or higher bacteria.

ii. The temperature of the water will affect the attractiveness to the extent that use by consumers will decrease if the water is of extremely high temperature. Ground water temperatures vary slightly from around 40 to 55 °F (4 to 13 °C). Such temperature changes are dependent upon well depth and aboveground storage facilities. Surface water temperatures vary with seasonal change from around 40 to 80 °F (4 to 27 °C).

2. **Bacterial quality of water**: The most important quality of water is that of bacteria content. In the early 20th century, disease outbreaks from water and food-borne bacteria were common throughout the world. Progress in bacteriology and water treatment engineering has all but eliminated outbreaks of water-borne communicable diseases.

3. **Water chemistry**: Water is an excellent solvent, so it is not surprising that it picks up other chemicals. During this cycle of water movement, water picks up many solid and gaseous components. As the raindrops fall to the earth, they absorb gases. Most gases within the atmosphere are carbon, sulphur and nitrogen compounds. The raindrops may also pick up particulate materials in the atmosphere.

   Many of the particulates are soluble in water and will dissolve within the raindrop.

   Other constituents are added to the water cycle from surface or ground water flow. Many and varied constituents are added to the water from dissolution of rocks and minerals which come in contact with the water and its movement. Of particular importance to the water supplier are the following constituents:

i. Acidity and alkalinity

ii. Calcium

iii. Carbon compounds
iv. Chlorides
v. Florides
vi. Iron
vii. Magnesium
viii. Manganese
ix. Nitrogen compounds
x. Silica
xi. Sulphur compounds.

2.5.0 Ground Water

Groundwater is fresh water (from rain or melting ice and snow) that soaks into the soil and is stored in the tiny spaces (pores) between rocks and particles of soil. Groundwater accounts for nearly 95 percent of the nation's fresh water resources. It can stay underground for hundreds of thousands of years, or it can come to the surface and help fill rivers, streams, lakes, ponds, and wetlands. Groundwater can also come to the surface as a spring or be pumped from a well. Both of these are common ways we get groundwater to drink.

In the original planning of ground water supplies, little can be done about determining the chemical quality of the water because the water will be obtained from several well-defied and different water bearing geological layers or strata. The chemical or mineral quality of the water contributed from each of these water-bearing formations or aquifers will be dependent on the dissolution of material within the formation. Therefore, water withdrawn from any ground water source will be a composite of these individual aquifers.

Before the 1970s, the study of life in groundwater habitats was relatively limited. In the 1970s, however, it became increasingly obvious that certain waste disposal practices were contaminating subsurface environments (Schaffter and Parriaux, 2002). There has also been an increasing interest in demonstrating that various shallow and deep environments contain substantial numbers of viable microorganisms to degrade potential pollutants, i.e. in bioremediation. Subsurface microbiological research to study microbial community structure, microbial activities and the geochemical properties of groundwater environments has progressed with the development of aseptic sampling techniques (Obuobie, and Barry, 2010).

In a hydrogeological sense, groundwater refers to water that is easily extractable from saturated, highly permeable strata known as aquifers (Pritchard, Mkandawire & O'Neil, 2008). For saturated environments, a rigorous distinction between local, intermediate, and regional flow systems, related to the topography of recharge and discharge areas has been long recognized by hydrologists. One can thus define several underground aquifers that serve as source of potable water in the world which can be classified as shallow aquifers, intermediate and deep aquifers (Morita, 1997).

Shallow aquifers are characterized by active flow strongly influenced by local precipitation events. Intermediate aquifers within 300 m of the surface soil are separated from shallow aquifers by confining layers; they have much slower flow rates, of the order of meters per year. Deep aquifers are also confined, but more than 300 m below the subsurface soil and they are characterized by extremely slow flow rates (meters per century, Obuobie, and Barry, 2010).

Groundwater is a key water resource in much of the world. Many major cities and small towns in the world depend on groundwater for their water supplies, mainly because of its abundance, stable quality and also because it is inexpensive to exploit. In developing countries, use of shallow groundwater sources for drinking and other domestic purposes is a common feature of many low-income communities (Howard *et al.*, 1999). The communities relying on such sources tend to be poor and live in polluted environments with associated high health risks (WHO and UNICEF, 2000). Such communities occur in most cities in developing countries, for example in Asia, Africa, Latin America and the Caribbean. Their occurrence is attributed to rapid urbanization where urban growth is associated with rapid expansion of small, unplanned urban centres and peri-urban settlements.

Advantages of Groundwater

a. Rocks act as a natural filter
b. No loss of water through evaporation
c. No requirement for expensive and environmentally damaging dams
d. Pumping costs low

Disadvantages

a. Sedimentary rocks and presence of aquifers
b. Surface subsidence
c. Pollutants have long residence time
d. Groundwater not always suitable for drinking

Example of groundwater are wells and springs.

1. Wells

Dug wells

Open or poorly covered well heads pose the commonest risk to well-water quality, since the water may then be contaminated by the use of inappropriate water-lifting devices by consumers. The most serious source of pollution is contamination by human and animal waste from latrines, septic tanks, and farm manure, resulting in increased levels of microorganisms, including pathogens.

Contamination of drinking-water by agrochemicals such as pesticides and nitrates is an additional and increasing problem for small-community supplies.

Dug wells are generally the worst groundwater sources in terms of faecal contamination, and bacteriological analysis serves primarily to demonstrate the intensity of contamination and hence the level of the risk to the consumer.

Various types of hand-dug wells are (shown in Fig. 2.1) ranging from poorly protected to well protect. The upgrading of unprotected wells and the construction of protected wells for community use should be strongly promoted.

Many tens of millions of families worldwide still depend on private and public dug wells; technical assessment and improvement of these wells is therefore very important. The commonest physical defects leading to faecal contamination of dug wells are associated with damage to, or lack of, a concrete plinth, and with breaks in the parapet wall and in the drainage channel. However, the most hazardous gross faecal contamination is most commonly associated with latrines sited too close to the well. Emergency relocation of either the latrines or the water source is essential when such serious problems are encountered.

An open dug well is little better than an unprotected hole in the ground if the above-mentioned physical barriers to surface-water contamination are not regularly maintained. The majority of open dug wells are contaminated, with levels of at least 100 faecal coliforms per 100ml, unless very strict measures are taken to ensure that contamination is not introduced by the bucket.

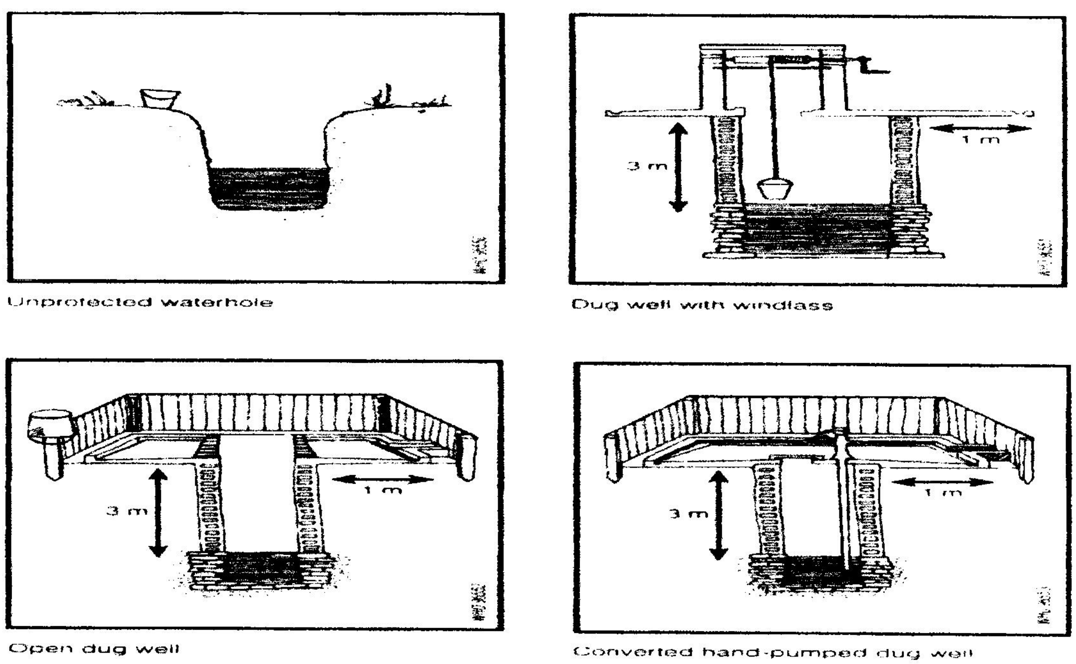

Figure 2.1: Dug well

2. Springs

A spring is any natural situation where water flows from an aquifer to the earth surface. A spring may be the result of karst topography where surface water has infiltrated the earth surface (recharge area), becoming part of the area groundwater. The forcing of the spring to the surface can be the result of a confined aquifer in which the recharge area of the spring water table rests at a higher elevation than that of the outlet.

If a spring is to be used as a source of domestic water:

- It should be of adequate capacity to provide the required quantity and quality of water for its intended use throughout the year
- It should be protected to preserve its quality.

Exposed springs are vulnerable to contamination from human and animal activities. The usual method of protecting springs is to collect the water where it rises by enclosing the eye of the spring in a covered chamber or box with an outlet near the bottom to allow water to flow away from the original site of the spring; in this way the natural spring is disturbed as little as possible.

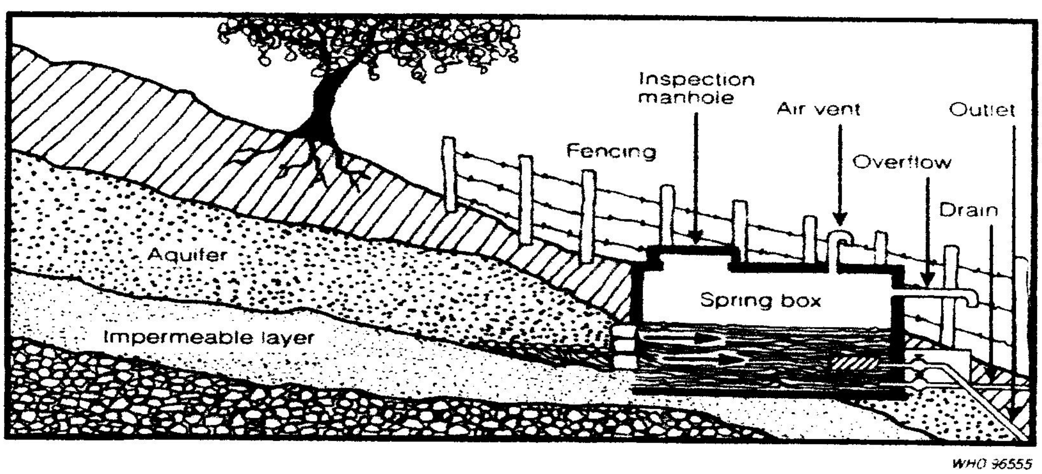

Figure 2.2: Protected gravity spring

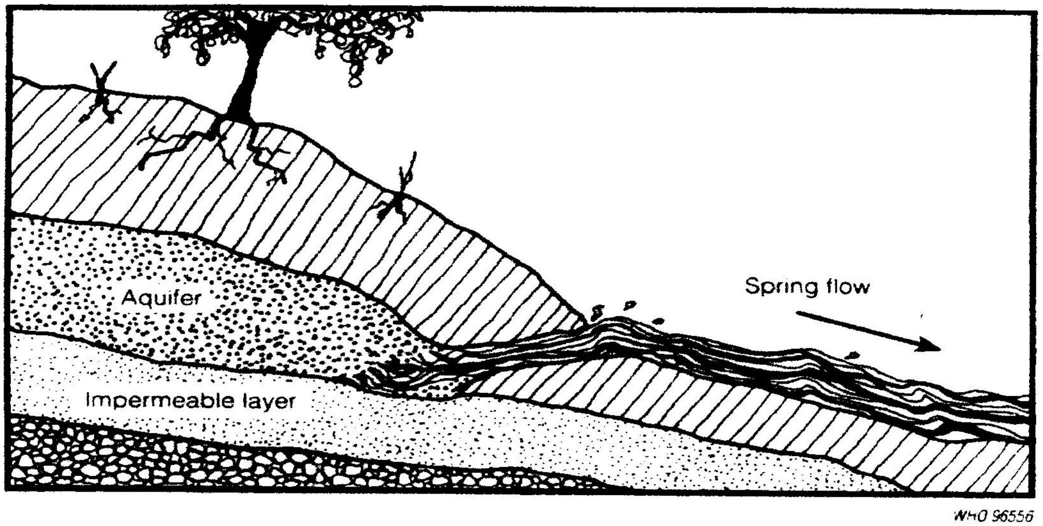

Figure 2.3: Unprotected gravity spring

2.5.1 Sources of Contamination of Groundwater

Groundwater is an important source of drinking water in many nations and may be heavily contaminated in many industrialized nations by industrial waste pits, septic tanks, oil wells, landfills, etc. Aquifers supply drinking water for about 120 million Americans and supply a quarter of the annual water demands in the United States. They are also a major supplier of water in many other countries. United States groundwater, scientists are now reporting, is increasingly threatened by pollution. Many pollutants are present at much higher concentrations in groundwater than they are in most contaminated surface supplies (Moyer and Morita, 2000). Also, many contaminants are tasteless and odourless at concentrations thought to be threatening human health.

According to Miller (1997), about 4500 billion litres of contaminated water seeps into the ground in the United States every day from septic tanks, cesspools, oil wells, landfills, agriculture, and ponds holding hazardous wastes. Unfortunately, very little is known about the extent of groundwater contamination. The Environmental Protection Agency of the United States of America (USEPA) estimates one percent (1%) of the drinking water wells in the United States has contaminants that exceed the standard designed to protect human health. Although that may seem small, 1% of hundreds of thousands of wells is a large number. In fact, one study reported that at least 8000 private, public and industrial wells in the U.S are contaminated (Miller, 1997).

2.5.2 Effects of Microbial Contaminants in Groundwater Quality

Groundwater quality can be influenced directly and indirectly by microbiological processes, which can transform both inorganic and organic constituents of groundwater. According to Mathess (1982), single and multi-celled organisms have become adapted to using the dissolved materials and suspended solids in the water and solid matter in the aquifer of their metabolism, and then releasing the metabolic products back into the water. There is practically no geological environment at or near, the earth's surface where the PH condition will not support some form of organic life (Chilton and West, 1992). In addition to groups tolerating extremes of PH, there are groups of microbes which prefer low temperatures (thermophiles), and yet others which are tolerant of high pressures. However, the most biologically favourable environments generally occur in warm, humid conditions.

Sulphides, for example, can be oxidized without microbial help, but microbial processes can greatly speed up oxidation to the extent that, under optimum moisture and temperature conditions, they become dominant over physical and chemical factors. All organic compounds can act as potential sources of energy for organisms. Most organisms require oxygen for respiration (aerobic respiration) and the breakdown of organic matter, but when oxygen concentrations are depleted some bacteria can use alternatives, such as nitrate, sulphate and carbon dioxide (anaerobic respiration).

According to Chiroma (2008), he stated that organisms which can live in the presence of oxygen (or without it) are known as facultative anaerobes. In contrast, obligate anaerobes are organisms which do not like oxygen. He presence or absence of oxygen is, therefore one of the most important factors affecting microbial activity, but not the only one.

2.5.3 Surface Water

Surface water sources are derived directly from stream and river flow or are stored prior to use, usually from behind high- or low-level dams that form water retention lakes anywhere from a few acres to many square miles in size. Factors such as chemical and bacterial quality greatly influence the economics of water treatment and the physical quality of the water. Surface water supplies are divided into two distinct classifications, filtered and unfiltered. These classifications are based upon the type of treatment necessary to produce potable water, and upon the quality of such water prior to any required treatment process.

2.5.4 Rainwater

Rainwater harvesting is a technique used for collecting, storing and using rainwater for landscape irrigation and other uses. The rainwater is collected from various hard surfaces such as rooftops or other manmade above ground surface.

In Uganda, the government has been piloting household rainwater harvesting with little or no subsidy for areas with poor groundwater. Results have been positive but dilemmas over subsidies have slowed progress down. In Mozambique miners returning from South Africa have brought necessary knowledge of technologies and also resources back with them, leading to a growth of self-financed rainwater harvesting in water scarce areas such as Inhambane and incremental improvement as resources allow

In many West African towns with high water tariffs similar developments of roof water catchment have been undertaken by households reluctant or unable to pay year-round for water by volume, or suffering from unreliable supplies. However, areas where rainwater can provide year-round supplies are limited by the pattern of rainfall in most countries

2.6 Water Quality Test

Testing procedures and parameters are grouped into physical, chemical and bacteriological.

1. Physical Test

Include Temperature, colour, odour and taste, turbidity, dissolved solids, total solids and suspended solid are recorded.

i. **Temperature:** 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.

ii. **Turbidity:** The raw water samples are commonly colored due to the presence of colloidal substance, inorganic impurity, aquatic growth and decomposition of vegetation.

   Turbidity can also indicate problems associated with treatment processes especially with coagulation/sedimentation and filtration.

iii. **Total Dissolve Solid (TDS):** indicates the general nature of salinity of water. Water with high TDS have salty taste and produce scales on cooking vessels and boilers. The palatability of water with a total dissolved solids (TDS) level of less than about 500 mg/l is generally considered to be good (WHO, 2006).

2. Chemical Test

Include PH, chlorides, hardness, acidity, iron, manganese, dissolved oxygen, biochemical oxygen demand

i. **PH:** The PH plays a very crucial part in waste water treatment and for fixing alum dose in water supply.

According to Kumar (2002), he reported that higher values of pH hasten the scale formation in water heating apparatus and reduce germicidal potential of chlorine. Water generally becomes more corrosive with decreasing PH. However, excessively alkaline water also may be corrosive (USEPA, 1994).

ii. **Chloride:** Large concentrations increase the corrosiveness of water and, in combination with sodium, give water a salty taste (USEPA 1994). WHO (2006)
recommended that when chloride exist in excess of 200-300mg/l, it impacts salty taste to water and people who are not accustomed to high chloride are subjected to laxative effect.

iii. **Hardness:** The total hardness has been attributed mainly due to Calcium and Magnesium (Patel and Sinha, 1998; WHO, 2006). The water containing excess hardness is not desirable for potable water as it forms scales on water heater and utensils when used for cooking and can result to excessive consumption of more soap during washing of clothes.

iv. **Magnesium:** The sources of Magnesium (Mg) in natural water are as a result of weathering of various types of rocks, industrial waste and sewage (Samantara *et al.* 2015).

v. **Iron:** The primary concern about iron in drinking water is its objectionable taste. Kidney stone related problem may develop if iron contents are high (WHO,2006). The presence of iron can also stains laundry and plumbing fixtures.

vi. **Biochemical Oxygen Demand (BOD):** This is the amount of oxygen required by bacteria to completely stabilize organic matter into Carbon-dioxide (CO_2) and Water (H_2O) under aerobic conditions. A high BOD is the presence of a large amount of organic pollution.

3. **Bacteriological Test:** this Total Bacteria Counts, Total Coliform Count, Enterobactersp, Thermo Tolerant Coliform or E. coli, Faecal Streptococcus, Clostridium Perfringens spore among others, are the most common bacteriological parameters found in ground water sources. However, the universal indicator organisms have been the Coliforms, specifically Escherichia coli, which normally originate from human and animal faeces.

2.7 Microbiological Quality of Drinking Water

2.7.1 Identifying microbial hazards in drinking water

A large variety of bacterial, viral and protozoan pathogens are capable of initiating waterborne infections. Some are primarily the enteric bacterial pathogens including classic agents such as Vibrio cholerae, Salmonella spp., Shigella spp., and newly recognized pathogens from faecal sources like Campylobacter jejuni and enterohemorrhagic E. coli. The survival potential of these bacteria increases in biofilms and due to their stages as VBNC (viable but non-culturable) cells (Wilson et al, 1983).

Several new bacterial pathogens such as Legionella spp., Aeromonas spp., P. aeruginosa and Mycobacterium avium have a natural reservoir in the aquatic environment and soil. These organisms are introduced from the surface water into the drinking water system usually in low numbers. They may survive and grow within the distribution system biofilm (Wilson et al, op cit.).

Again, more than 15 different groups of viruses, encompassing more than 140 distinct types, can be found in the human gut. These enteric viruses are excreted by patients and find their way into sewage. Hepatitis A and E viruses cause illness (hepatitis) unrelated with gut epithelium. Another specific group of viruses has been incriminated as a cause of acute gastroenteritis in humans; it includes rotavirus, calicivirus, the most notorious being Norwalk virus, astrovirus and some enteric adenovirus. These viruses cannot grow in the receiving water and may only remain in small number or die off (Szyweck et al, 2000).

The most prevalent enteric protozoa, associated with water-borne disease, include Giardia lamblia and Cryptosporidium parvum. In addition, protozoa like Cyclospora, Isospora and many microsporidian species are emerging as opportunist pathogens and may have waterborne routes of transmission (Szyweck et al, op cit.). Like viruses, protozoa cannot multiply in the receiving waters. With the exception of Salmonella, Shigella and hepatitis A virus, all the other organisms can be so-called 'new or emerging pathogens'. There are a number of reasons for the emergence of these new pathogens. They include high resistance of viruses and protozoan cysts, a lack of identification methods for viruses, change in habit of water use (Legionella) and subpopulations at risk.

Another striking epidemiological feature is the low number of bacteria that can trigger disease. The infectious dose of Salmonella is in the range of 107–108 cells while only around 100 cells are required to cause clinical illness with E. coli 0157:H7 and Campylobacter. The infective dose of enteric viruses is low, typically in the range of 1 – 10 infectious units; it is about 10 – 100 oocysts for Cryptosporidium (Szewzyck et al, 2000).

2.8 Assessment of Microbial Risks

The view on the microbiological safety of drinking water is changing. The demand for the total absence of any pathogenic organism is no longer significant in light of the new pathogens, some of which are capable of growing in drinking water systems. According to the new European Union Council directive 98/83/EC, water for human consumption must be free from any microorganisms and parasites and from any substances which, in numbers or concentrations, constitute a potential danger to human health (European Union Council, 1998). To deal with this issue, the U.S. Environmental Protection Agency for the first time used a microbial risk assessment approach. It has been defined that an annual risk of 1, 034 (one infection per 10 000 consumers per year) should be acceptable for diseases acquired through potable water, this value being close to the annual risk of infection from waterborne disease outbreaks in the United States.

Microbiological risk assessment is a major tool for decision making in the regulatory area. The problem is, however, that the key data to perform this assessment are mostly missing. Few epidemiological studies associating the incidence of disease to the pathogen densities have been reported. Several outcomes, from asymptomatic infection to death, are possible through exposure to microbes (Szyweck *et al*, *op cit.*). The issue of dose-response relationships is particularly striking: these relationships are only available for a few pathogens; when infectious doses are low as is the case for some viruses and protozoan cysts, the calculated tolerable concentrations are also low and monitoring of these pathogens in drinking water becomes impracticable (Miller, 1997).

2.8.1 Faecal Coliform Organisms

Faecal coliforms are one of the most important parameters to consider when assessing the suitability of drinking water because of the infectious disease risk. Faecal coliforms indicate contamination by mammals and birds' waste (faeces) and signify the possible presence of pathogenic bacteria and viruses which are responsible for water-related diseases such as cholera, typhoid and other diarrhoeal-related illnesses. One gram of faeces is reported to contain 10,000,000 viruses; 1,000,000 bacteria; 1000 parasite cysts; and 100 parasite eggs (UNESCO, 2007). Zero faecal cfu/100 ml is considered uncontaminated (WHO, 2006; MBS, 2005); 50 faecal cfu/100 ml is regarded suitable by MoWD (2003) for untreated water.

2.8.2 Total Coliforms

The most commonly measured indicators of water quality are the coliform organisms. Gram negative bacteria are cytochrome oxidate negative, non-spore forming, and ferment lactose at 35^0C–37^0C, within 24–48 hours (Morita, *op cit.*) this defines total coliforms. The group is as diversified as their habits from which they originate. Thus the total coliform group should not be regarded as an indicator of organisms exclusively from faecal origins especially in hot countries where coliforms of non-faecal origins are common. In the presence of organic material and under suitable conditions, coliforms multiply. Measurement of faecal coliforms is a better indicator of general contamination of faecal origin. Faecal coliforms differ from the other members of the total coliform groups on the grounds that they tolerate and grow at higher temperatures of 44-45°C. Presumptive *Escherichia coli* convert tryptophan to indole. They are permanent species among the faecal coliforms (Szyweck *et al*, *op cit.*).

2.8.3 Presence of Bacteria

The presence of bacteria is of great importance in the water industry with regards to water-borne diseases. Some of such diseases are dysentery, typhoid fever, paratyphoid fever, cholera, infantile paralysis, poliomyelitis, infectious hepatitis, guinea worm, amoebic dysentery, etc. (Szyweck *et al*, *op cit.*). Transmission of the causative micro-pathogenic organism is through direct or indirect contamination of water source by human excreta. Since it is extremely difficult to isolate and identify different forms of pathogens, the microorganisms which are of significance to water quality are those of enteric pathogenic origin (Szyweck *et al*, *op cit*).

CHAPTER THREE

3.0 METHODOLOGY

Asin-Ekiti community is situated in Ikole-ekiti, Ekiti, Nigeria. It is located in south-western Nigeria on longitude7° 47′ 0″ North and latitude 5° 31′ 0″ East. The predominant mother tongue spoken in Asin-ekiti of Ikole, Ekiti State is Yoruba. It has an area of 321 km^2 and a population of 168,436 at the 2006 census. Asin-Ekiti of Ikole Local Government Area is situated in the deciduous forest area of the State. Rainfall is about 70 inches 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.

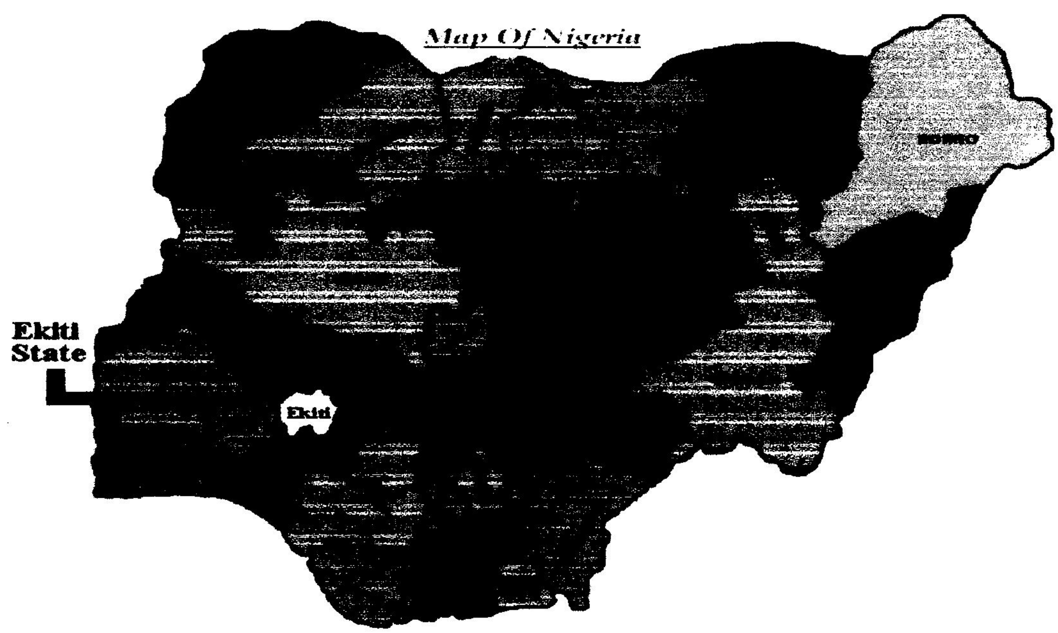

Fig 3.1: Map of Nigeria showing Ekiti State

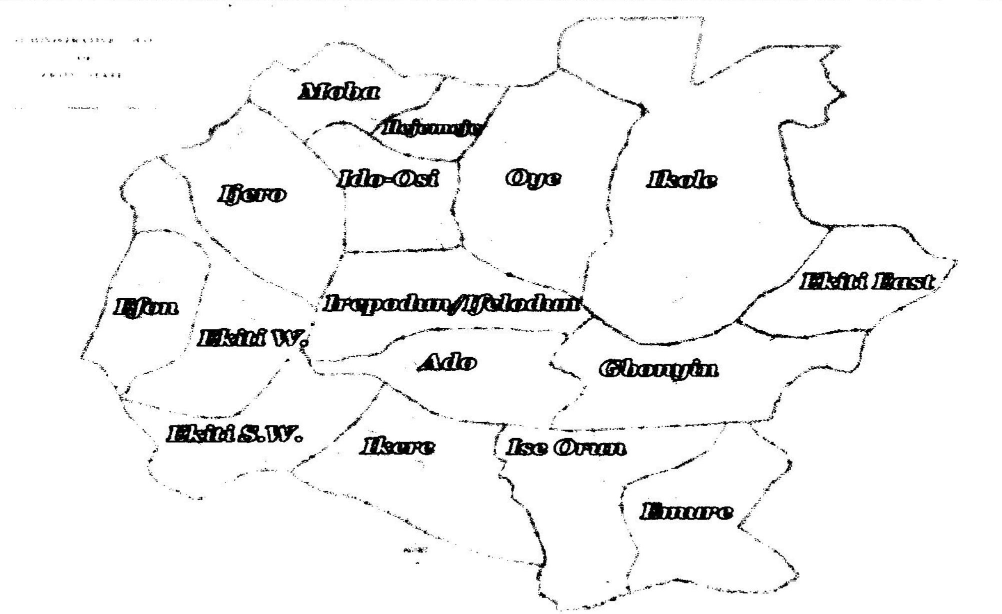

Fig 3.2: Map of Ekiti State showing all Local Government Area of the State

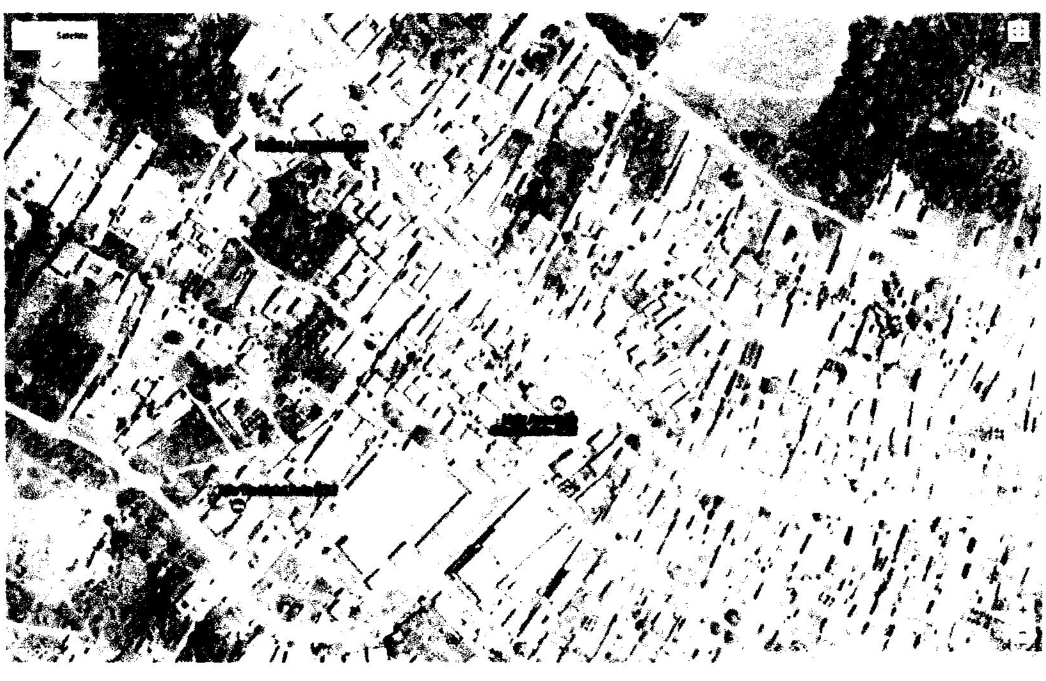

Fig 3.3: Map of Asin-Ekiti of Ikole LGA showing some street on google map

Selections of Wells

Asin-Ekiti of Ikole L.G.A was divided into zones based on street locations for stratified sampling, twenty hand dug were randomly selected from eight (8) streets, with selection of two hand-dug well from four streets (A-D) and three hand-dug well from other four streets (E-H).

The criteria for the selection of wells in this community were based primarily on the construction pattern and mode of operation of the wells. The different streets are elaborated briefly as:

Table 3.1: Name, Construction pattern and Mode of operation

Zone	Name	Construction pattern	Mode of operation
A	Akintola street	Semi-protected	Bucket and rope
B	DS Ajayi street	Well protected	Bucket and rope
C	PA John olatuyi street	Well protected	Bucket and rope
D	Emmanuel Adeyemo street	Semi-protected	Bucket and rope
E	Mic-Vic hotel street	Semi-protected	Bucket and rope
F	Ona Iye street	Well-protected	Bucket and rope
G	Ifesowapo street	Semi-protected	Bucket and rope
H	Palace Way	Semi-protected	Bucket and rope

Table 3.2: GPS Location of the water source

ZONE	WATER SOURCE NAME	SAMPLE NO	GPS LOCATION
A	Akintola street	HDW_1	7. 475990^{0}N 5.295354^{0}E
		HDW_2	7.475998^{0}N 5.295213^{0}E
B	DS Ajayi street	HDW_3	7.475926^{0}N 5.294660^{0}E
		HDW_4	7.476339^{0}N 5.294772^{0}E
C	PA John olatuyi street	HDW_5	7.473203^{0}N 5.294344^{0}E
		HDW_6	7.472311^{0}N 5.293932^{0}E
D	Emmanuel Adeyemo street	HDW_7	7.472193^{0}N 5.293594^{0}E
		HDW_8	7.472190^{0}N 5.293486^{0}E
E	Mic-Vic hotel street	HDW_9	7.473681^{0}N 5.294868^{0}E
		HDW_{10}	7.473447^{0}N 5.294611^{0}E
		HDW_{11}	7.473731^{0}N 5.294403^{0}E
F	Ona Iye street	HDW_{12}	7.475558^{0}N 5.294668^{0}E
		HDW_{13}	7.475727^{0}N 5.294488^{0}E
		HDW_{14}	7.474591^{0}N 5.293986^{0}E
G	Ifesowapo street	HDW_{15}	7.474767^{0}N 5.294819^{0}E
		HDW_{16}	7.474886^{0}N 5.294339^{0}E
		HDW_{17}	7.474535^{0}N 5.294824^{0}E
H	Palace Way	HDW_{18}	7.473879^{0}N 5.295811^{0}E

	Palace Way	HDW_{19}	7.472324^{0}N 5.295333^{0}E
	Palace Way	HDW_{20}	7.471733^{0}N 5.295084^{0}E

Domestic Water Samples are to be collected from twenty hand-dug well within Asin community area of Ikole L.G.A different locations and these samples serve as representation of the groundwater supplies. The sample bottles for collection is going to be sterilize before using it.

The following water quality parameters is going to be analyze in the laboratory base on physical, chemical and biological test comparing it with Nigeria Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO).

Table 3.3: Physical, Chemical and Bacteriological parameters (NSDWQ/WHO)

Parameters	Unit	Max. Permitted Level		Health
		NSDWQ	WHO	
Colour	TCU	15	3	None
Odour	-	Unobjectionable	Unobjectionable	None
Taste	-	Unobjectionable	Unobjectionable	None
Temperature	^{0}Celcius	Ambient	Ambient	None
Turbidity	NTU	5	5.4	None
Chloride (Cl)	mg/L	250	100	None

Copper (Cu^{2+})	mg/L	1	2	Gastrointestinal disorder
Zinc	mg/L	3	3	None
Hardness (as $CaCO_3$)	mg/L	150	75	None
Magnesium (Mg^{2+})	mg/L	0.20	50	Consumer acceptability
Nitrate (NO_3)	mg/L	50	50	Cyanosis, and asphyxia (blue-baby syndrome) in infants under 3 months
pH	-	6.5-8.5	6.5-8.5	None
Sodium (Na)	mg/L	200	200	None
Sulphate (SO_4)	mg/L	100	200	None
Total Dissolve Solid (TDS)	mg/L	500	500	None
Total Coliform count	cfu/mL	10		Indication of faecal contamination
Conductivity	µS/cm	1000	1400	None

3.1 Hazard Analysis

Hazards analysis is based on identifying potential risks in systems and preferring solutions to eliminate/ manage the risks accordingly. The following tables are used to monitor the various types and sources of hazards and how they can be identified (from catchment to consumer point of use)

Table 3.4: Identification of Sources of Hazards

Hazardous event	**Associated hazards (and issues to consider)**
Poor Water Quality	Contaminants in vicinity of water source
Location of septic tanks	Microbial contamination
Well/borehole headwork not water tight	Surface water intrusion
Flooding around water source	Water Quality compromised

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

4.1 RESULTS

The study focused on the physical, chemical and biological parameter of domestic water self-supply from twenty hand-dug well in Asin-Ekiti community of ikole local government area.

Table 4.1: Site of Project

ZONE	WATER SOURCE NAME	SAMPLE NO
A	Akintola street	HDW_1
		HDW_2
B	DS Ajayi street	HDW_3
		HDW_4
C	PA John olatuyi street	HDW_5
		HDW_6
D	Emmanuel Adeyemo street	HDW_7
		HDW_8
E	Mic-Vic hotel street	HDW_9
		HDW_{10}
		HDW_{11}
F	Ona Iye street	HDW_{12}
		HDW_{13}

		HDW_{14}
G	Ifesowapo street	HDW_{15}
		HDW_{16}
		HDW_{17}
H	Palace Way	HDW_{18}
	Palace Way	HDW_{19}
	Palace Way	HDW_{20}

Table 4.2: Result of Physical Parameters of samples from HDW1 to HDW4

S/N	TESTS	RESULT				RECOMMENDED LIMITS	
		HDW_1	HDW_2	HDW_3	HDW_4	NSDWQ	WHO
1	Colour (TCU)	ND	ND	ND	ND	15	3
2	Odour	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
3	Taste	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
4	Temperature °C	26.2	26.7	26.0	26.3	Ambient	Ambient

KEYS

ND- ***Not Detected***

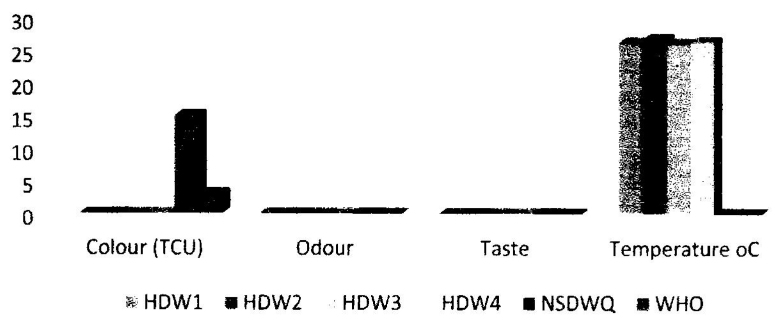

Figure 4.1: The chart of physical parameters against NSDWQ/WHO

Table 4.3: Result of Physical Parameters of samples from HDW5 to HDW8

S/N	TESTS	RESULT				RECOMMENDED LIMITS	
		HDW_5	**HDW_6**	**HDW_7**	**HDW_8**	NSDWQ	WHO
1	Colour (TCU)	**ND**	**ND**	**ND**	**ND**	15	3
2	Odour	**Unobjectionable**	**Unobjectionable**	**Unobjectionable**	**Unobjectionable**	**Unobjectionable**	Unobjectionable
3	Taste	Unobjecti	Unobjecti	Unobjecti	Unobjecti	Unobjecti	Unobjecti

		onable	onable	onable	onable	onable	onable
4	Temper ature °C	26.2	26.4	26.2	26.4	Ambient	Ambient

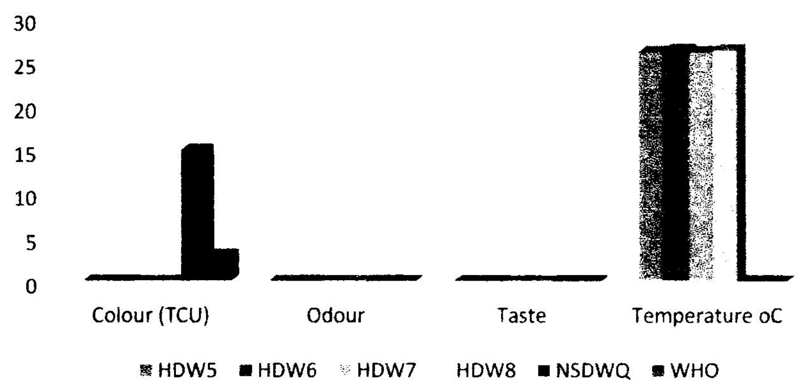

Figure 4.2: The chart of physical parameters against NSDWQ/WHO

Table 4.4: Result of Physical Parameters of samples from HDW9 to HDW12

S/N	TESTS	RESULT				RECOMMENDED LIMITS	
		HDW_9	HDW_{10}	HDW_{11}	HDW_{12}	NSDWQ	WHO
1	Colour (TCU)	ND	ND	ND	ND	15	3
2	Odour	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
3	Taste	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
4	Temperature °C	27.0	26.3	28.7	26.4	Ambient	Ambient

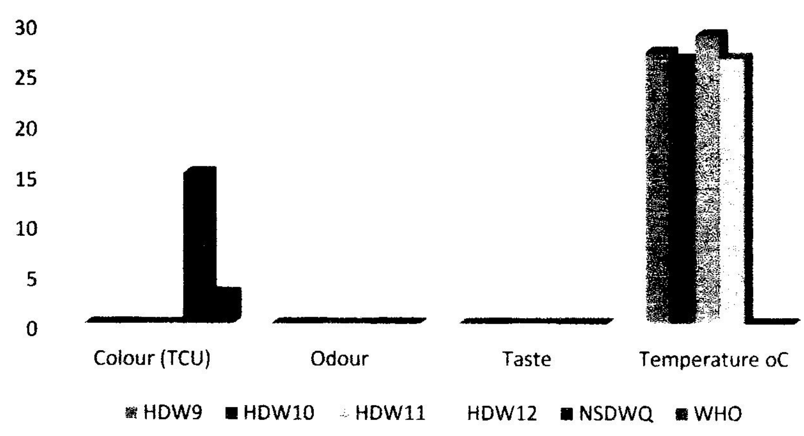

Figure 4.3: The chart of physical parameters against NSDWQ/WHO

Table 4.5: Result of Physical Parameters of samples from HDW13 to HDW16

S/N	TESTS	RESULT				RECOMMENDED LIMITS	
		HDW_{13}	HDW_{14}	HDW_{15}	HDW_{16}	NSDWQ	WHO
1	Colour (TCU)	ND	ND	ND	ND	15	3
2	Odour	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
3	Taste	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
4	Temperature °C	28.5	26.4	28.0	28.4	Ambient	Ambient

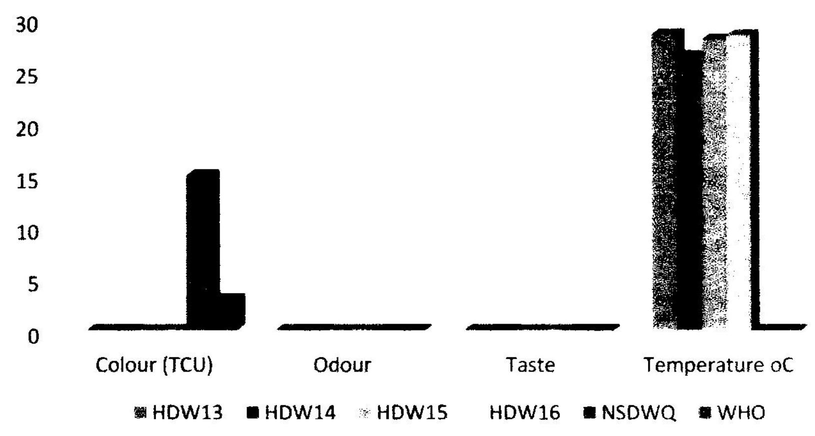

Figure 4.4: The chart of physical parameters against NSDWQ/WHO

Table 4.6: Result of Physical Parameters of samples from HDW17 to HDW20

S/N	TESTS	RESULT				RECOMMENDED LIMITS	
		HDW_{17}	HDW_{18}	HDW_{19}	HDW_{20}	NSDWQ	WHO
1	Colour (TCU)	ND	ND	ND	ND	15	3
2	Odour	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
3	Taste	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
4	Temperature °C	28.7	28.2	28.4	28.7	Ambient	Ambient

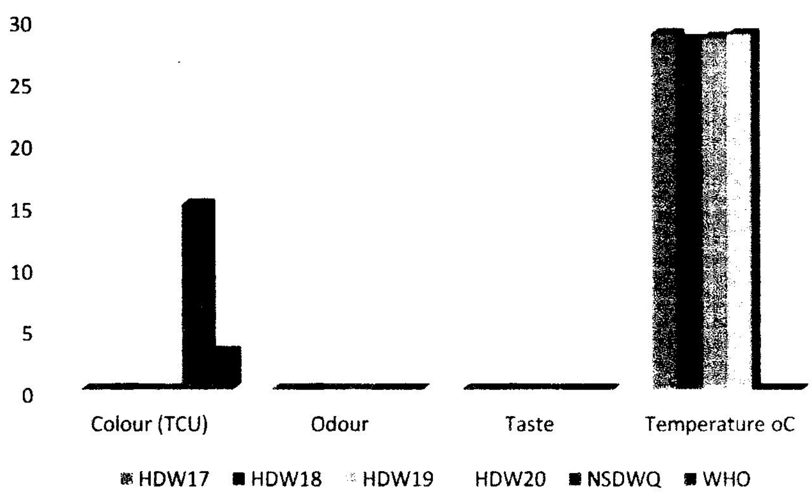

Figure 4.5: The chart of physical parameters against NSDWQ/WHO

Table 4.7: Result of Chemical Parameters of samples from HDW_1 to HDW_4

S/N	TESTS	RESULT				RECOMMENDED LIMIT	
		HDW_1	HDW_2	HDW_3	HDW_4	NSDWQ	WHO
1	pH	5.64	5.61	5.93	5.38	6.5-8.5	6.5-8.5
2	Chloride (mg/L)	6.00	5.00	5.80	4.40	250	100
3	Copper (mg/L)	ND	ND	ND	ND	1	2
4	Total Hardness as $CaCO_3$ (mg/L)	15.20	14.40	15.60	16.40	150	75
5	Magnesium (mg/L)	8.90	7.50	8.10	8.60	0.20	50
6	Nitrate (mg/L)	0.86	0.53	0.90	0.88	50	50
7	Sulphate (mg/L)	28.40	28.10	29.20	29.60	100	200
8	Zinc (mg/L)	0.36	0.26	0.21	0.30	3	3
9	TDS (mg/L)	0.52	0.42	0.40	0.47	500	1000
10	Conductivity (µS/cm)	88.20	53.80	181.30	96.80	1000	1400

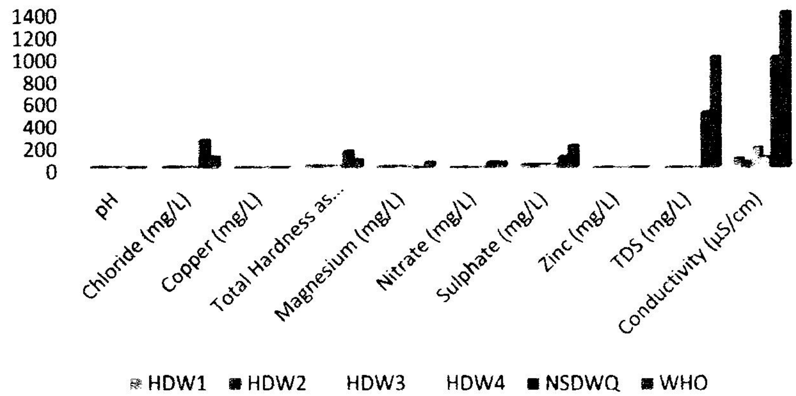

Figure 4.6: The chart of chemical parameters against NSDWQ/WHO

Table 4.8: Result of Chemical Parameters of samples from HDW_5 to HDW_8

S/N	TESTS	RESULT				RECOMMENDED LIMIT	
		HDW_5	HDW_6	HDW_7	HDW_8	NSDWQ	WHO
1	pH	5.99	6.83	6.74	6.74	6.5-8.5	6.5-8.5
2	Chloride (mg/L)	5.40	6.50	5.60	5.20	250	100
3	Copper (mg/L)	ND	ND	ND	ND	1	2
4	Total Hardness as $CaCO_3$ (mg/L)	16.00	12.00	11.20	18.80	150	75

5	Magnesium (mg/L)	7.70	6.30	5.40	9.60	0.20	50
6	Nitrate (mg/L)	0.92	0.90	0.96	0.94	50	50
7	Sulphate (mg/L)	28.50	26.80	25.90	30.20	100	200
8	Zinc (mg/L)	0.31	0.37	0.34	0.38	3	3
9	TDS (mg/L)	0.61	0.69	0.66	0.72	500	1000
10	Conductivity (μS/cm)	121.30	110.80	166.30	153.30	1000	1400

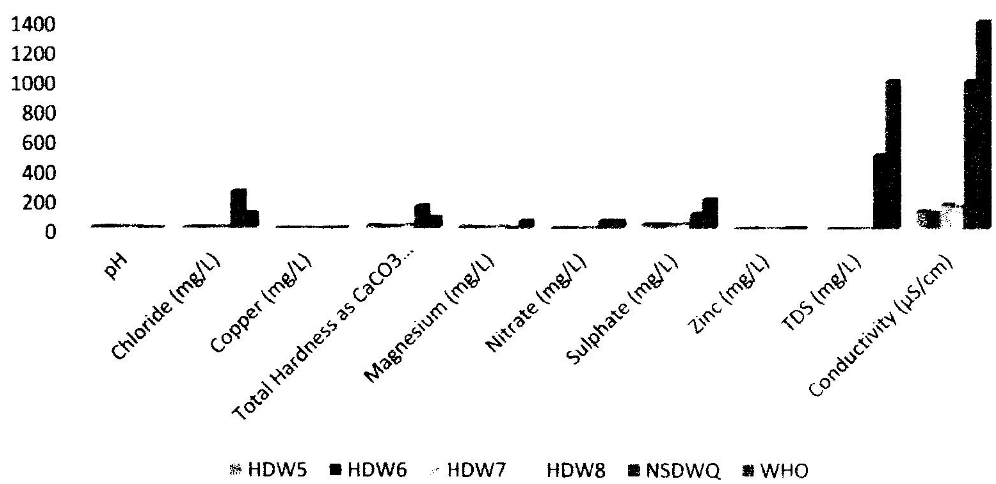

Figure 4.7: The chart of chemical parameters against NSDWQ/WHO

Table 4.9: Result of Chemical Parameters of samples from HDW_9 to HDW_{12}

S/N	TESTS	RESULT				RECOMMENDED LIMIT	
		HDW_9	HDW_{10}	HDW_{11}	HDW_{12}	NSDWQ	WHO
1	pH	6.63	5.54	7.31	6.27	6.5-8.5	6.5-8.5
2	Chloride (mg/L)	4.50	4.60	6.00	4.80	250	100
3	Copper (mg/L)	ND	ND	ND	ND	1	2
4	Total Hardness as $CaCO_3$ (mg/L)	16.10	15.20	16.00	11.60	150	75
5	Magnesium (mg/L)	8.20	7.10	8.40	5.30	0.20	50
6	Nitrate (mg/L)	0.83	0.78	0.97	0.99	50	50
7	Sulphate (mg/L)	29.30	29.10	28.70	26.00	100	200
8	Zinc (mg/L)	0.35	0.40	0.36	0.41	3	3
9	TDS (mg/L)	0.65	0.78	0.74	0.77	500	1000
10	Conductivity (µS/cm)	87.80	74.80	173.60	261.00	1000	1400

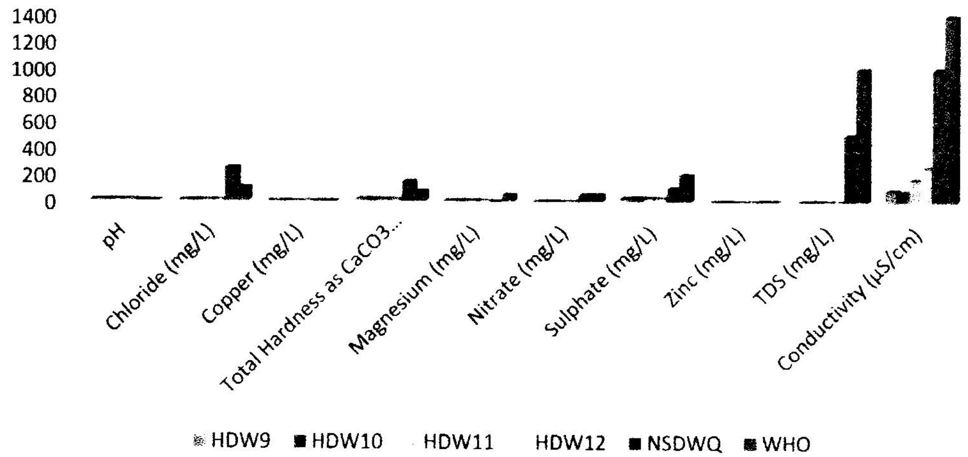

Figure 4.8: The chart of chemical parameters against NSDWQ/WHO

Table 4.10: Result of Chemical Parameters of samples from HDW_{13} to HDW_{16}

S/N	TESTS	RESULT				RECOMMENDED LIMIT	
		HDW_{13}	HDW_{14}	HDW_{15}	HDW_{16}	NSDWQ	WHO
1	pH	6.89	6.64	6.22	6.10	6.5-8.5	6.5-8.5
2	Chloride (mg/L)	6.20	5.50	6.00	5.90	250	100
3	Copper (mg/L)	ND	ND	ND	ND	1	2
4	Total Hardness as $CaCO_3$ (mg/L)	12.80	14.40	13..70	18.40	150	75

5	**Magnesium (mg/L)**	6.20	8.20	8.60	7.80	0.20	50
6	Nitrate (mg/L)	0.95	0.85	0.92	0.96	50	50
7	Sulphate (mg/L)	27.10	28.30	29.20	30.00	100	200
8	Zinc (mg/L)	0.40	0.39	0.42	0.38	3	3
9	TDS (mg/L)	0.69	0.54	0.70	0.68	500	1000
10	Conductivity (μS/cm)	148.10	150.40	208.60	268.50	1000	1400

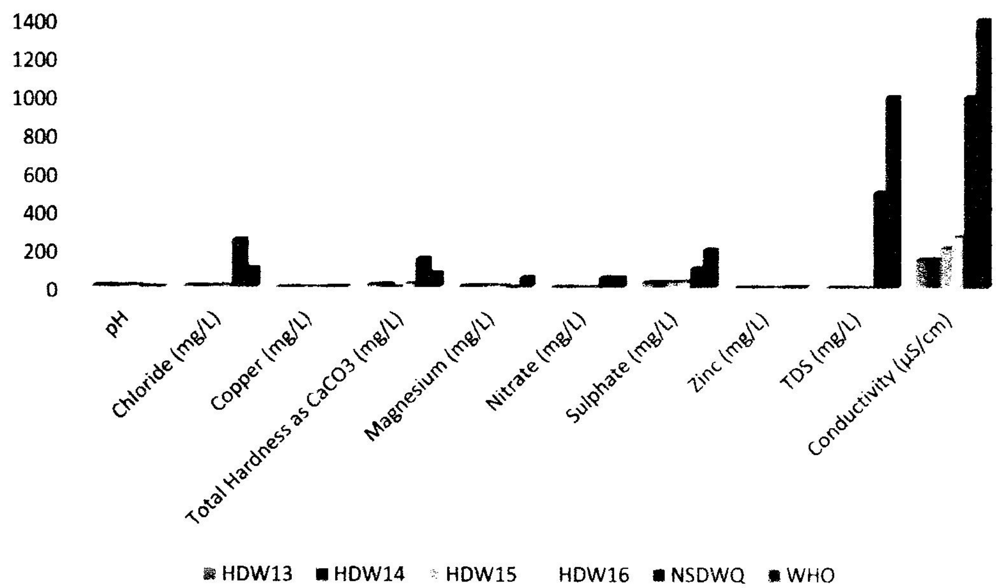

Figure 4.9: The chart of chemical parameters against NSDWQ/WHO

Table 4.11: Result of Chemical Parameters of samples from HDW_{17} to HDW_{20}

S/N	TESTS	RESULT				RECOMMENDED LIMIT	
		HDW_{17}	HDW_{18}	HDW_{19}	HDW_{20}	NSDWQ	WHO
1	pH	7.00	7.04	7.14	7.21	6.5-8.5	6.5-8.5
2	Chloride (mg/L)	8.20	7.10	4.80	6.50	250	100
3	Copper (mg/L)	ND	ND	ND	ND	1	2
4	Total Hardness as $CaCO_3$ (mg/L)	13.60	17.20	18.00	16.80	150	75
5	Magnesium (mg/L)	6.10	7.90	8.80	8.60	0.20	50
6	Nitrate (mg/L)	0.98	0.96	0.94	0.89	0.20	11
7	Sulphate (mg/L)	26.50	29.40	29.90	28.90	100	200
8	Zinc (mg/L)	0.42	0.43	0.41	0.39	3	3
9	TDS (mg/L)	0.72	0.65	0.64	0.59	500	1000
10	Conductivity (µS/cm)	251.60	311.50	153.00	101.80	1000	1400

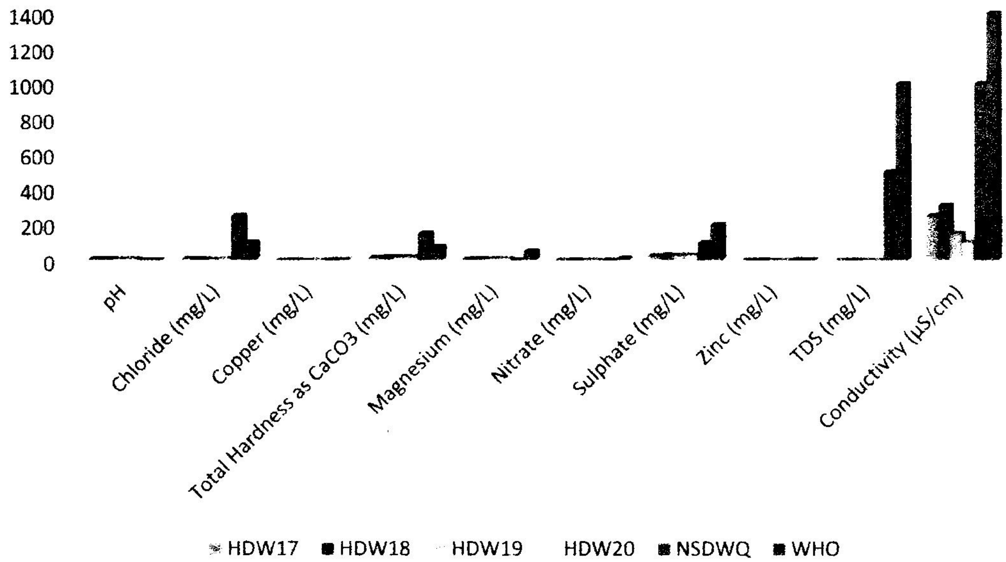

Figure 4.10: The chart of chemical parameters against NSDWQ/WHO

Table 4.12: Result of Bacteriological Parameters of samples from HDW_1 to HDW_4

S/N	TESTS	RESULT				RECOMMENDED LIMIT	
		HDW_1	HDW_2	HDW_3	HDW_4	NSDWQ	WHO
1	Total coliform count (cfu/mL)	10.0	10.0	10.0	14.0	10	0

Table 4.13: Result of Bacteriological Parameters of samples from HDW_5 to HDW_8

S/N	TESTS	RESULT				RECOMMENDED LIMIT	
		HDW_5	HDW_6	HDW_7	HDW_8	NSDWQ	WHO
1	Total coliform count (cfu/mL)	20.0	25.0	22.0	34.0	10	0

Table 4.14: Result of Bacteriological Parameters of samples from HDW_9 to HDW_{12}

S/N	TESTS	RESULT				RECOMMENDED LIMIT	
		HDW_9	HDW_{10}	HDW_{11}	HDW_{12}	NSDWQ	WHO
1	Total coliform count (cfu/mL)	32.0	31.0	29.0	30.0	10	0

Table 4.15: Result of Bacteriological Parameters of samples from HDW_{13} to HDW_{16}

S/N	TESTS	RESULT				RECOMMENDED LIMIT	
		HDW_{13}	HDW_{14}	HDW_{15}	HDW_{16}	NSDWQ	WHO
1	Total coliform count (cfu/mL)	31.0	29.0	32.0	30.0	10	0

Table 4.16: Result of Bacteriological Parameters of samples from HDW_{17} to HDW_{20}

S/N	TESTS	RESULT				RECOMMENDED LIMIT	
		HDW_{17}	HDW_{18}	HDW_{19}	HDW_{20}	NSDWQ	WHO
1	Total coliform count (cfu/mL)	31.0	29.0	27.0	26.0	10	0

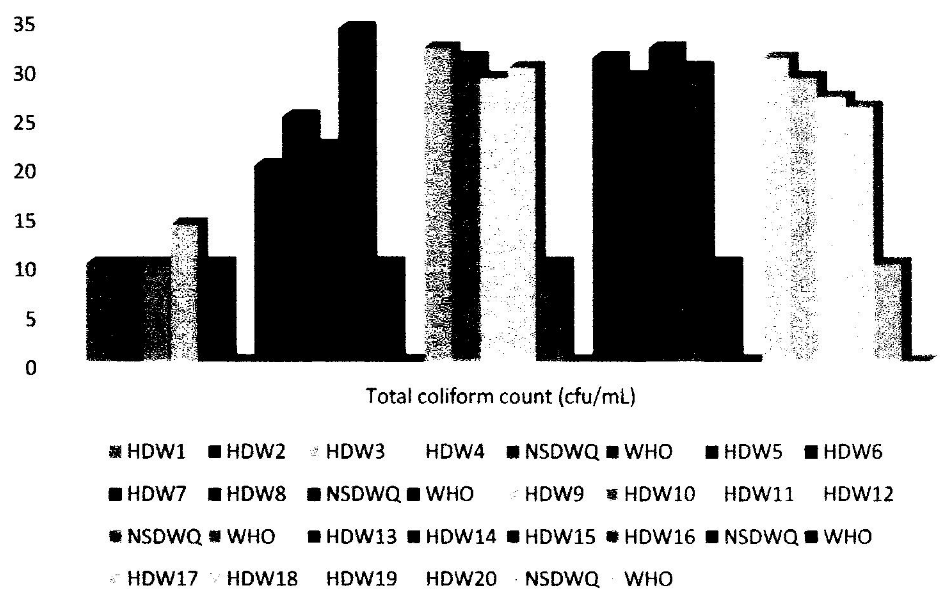

Figure 4.11: The chart of Bacteriological parameters against NSDWQ/WHO

4.2 Analysis of Results and Discussion

4.2.1 Temperature

The temperatures of water samples obtained from twenty hand-dug wells in Asin-ekiti of Ikole LGA ranged between 26.4°C and 28.7°C, respectively. Although, both NSDWQ and WHO have not defined temperature values for drinking water, all the values exceeded the normal room temperature of 22°C. This can be acceptable because it could be due to the weather condition of the area at the period of sample collection.

4.2.2 pH

The pH of samples 1,2,3,4,5,10,15 and 16 were slightly below NSDWQ/WHO Limit, therefore the pH can be increased using;

i. Water Softener which rely on an ion-exchange system
ii. Soda Ash
iii. Neutralizing Filters which increase pH values through the addition of neutralizing materials.

4.2.3 Conductivity

The Conductivity of all the samples were within NSDWQ/WHO recommended limit.

4.2.4 Chloride

The Chloride detected in all samples were within the NSDWQ/WHO recommended limit.

4.2.5 Nitrate

The Nitrate detected in all samples were below NSDWQ/WHO recommended limit and higher levels of nitrate in water can result from pollution by animal waste, or by seepage of human sewage or by the excess use of fertilizers.

4.2.6 Magnesium

The Magnesium content of all samples were above NSDWQ recommended limit but within WHO recommended limit.

4.2.7 Total Hardness

The Water Hardness of all samples were within the NSDWQ/WHO recommended limit.

4.2.8 Sulphate

The Sulphate of all samples were within the NSDWQ/WHO recommended limit.

4.2.9 Zinc

The Zinc content of all samples were within the NSDWQ/WHO recommended limit.

4.2.10 Copper

The Copper content was not detected in any of the samples.

4.2.11 Total Coliform count

The Total Coliform count of Sample 1,2 and 3 were within NSDWQ recommended limit but all the remaining samples were above recommended limit which show evidence of contamination with moderate risk. The contamination can be as a result of;

i. Environmental contamination due to contact with vegetation or soil

ii. Faecal contamination

The water sources can be decontaminated by Chlorination.

4.3 The Results of the Hazard Analysis are given in Tables 4.17 to 4.20

Table 4.17: Hazard Event - Septic Tank Location

rd :	Water source	Associated Hazard	Cause	Risk	Critical Limits		Corrective Action	Monitoring		
					Current Situation	Target		What	When	Who
	HDW1			No observed risk	Acceptable		None			
	HDW2			No observed risk	Acceptable		None			
	HDW3			No observed risk	Acceptable		None			
	HDW4			No observed risk	Acceptable		None		Bi-annually	
ion otic	HDW5		Facility location	No observed risk	Acceptable		None	Location of New Sanitary Facilities		
r	HDW6			No observed risk	Acceptable		None			
e	HDW7	Microbial Contamination		No observed risk	Acceptable		None			Designated Personnel
	HDW8			No observed risk	Acceptable		None			
	HDW9			No observed risk	Acceptable		None			
	HDW10			No observed risk	Acceptable		None			
	HDW11			No observed risk	Acceptable		None			

	HDW12			No observed risk	Acceptable		None			
	HDW13			Risk observed	Not Acceptable		Relocate the distance			
	HDW14			No observed risk	Acceptable		None			
	HDW15			No observed risk	Acceptable		None			
	HDW16			No observed risk	Acceptable		None			
	HDW17			No observed risk	Acceptable		None			
	HDW18			No observed risk	Acceptable		None			
	HDW19			Risk observed	Not Acceptable		Relocate the distance	Location of New Sanitary Facilities	Bi-annually	Designated Personnel
	HDW20			No observed risk	Acceptable		None			

Table 4.18: Hazard Event - Poor Water Quality

ard nt	Water Source	Associated Hazard	Cause	Risk	Critical Limits		Corrective Action	Monitoring		
					Current Situation	Target		What	When	Who
	HDW1		Not Applicable	No Observed Risk	Acceptable		Install hand pump on	Water		Designated Personnel

	HDW2		Not Applicable	No Observed Risk	Acceptable		water source	Quality	Weekly	
	HDW3		Not Applicable	No Observed Risk	Acceptable					
.	HDW4	Contaminant in Vicinity of Water Source	Microbial Contamination	Low Risk	Clearing of bushes around the source	Protected Water Source				
er lity	HDW5		Microbial Contamination	Low Risk	Not well covered	Protected Water Source				Designated Personnel
	HDW6		Microbial Contamination	Low Risk	Clearing of bushes around the source	Protected Water Source	Install hand pump on water source	Water Quality		
	HDW7		Microbial Contamination	Low Risk	Vicinity not clean	Protected Water Source			Weekly	
	HDW8		Microbial Contamination	Low Risk	Vicinity not clean	Protected Water Source				
	HDW9		Microbial Contamination	Low Risk	Refuse dump near the source	Protected Water Source				
	HDW10		Microbial Contamination	Low Risk	Not well covered	Protected Water Source				
	HDW11		Microbial	Low Risk	Refuse dump near	Protected Water				

			Contamination		the source	Source				
HDW12			Microbial Contamination	Low Risk	Animal faece around source	Protected Water Source				
HDW13			Microbial Contamination	Low Risk	Vicinity not clean	Protected Water Source			Weekly	
HDW14			Microbial Contamination	Low Risk	Vicinity not clean	Protected Water Source		Water Quality		Designated Personnel
HDW15			Microbial Contamination	Low Risk	Vicinity not clean	Protected Water Source	Install hand pump on water source			
HDW16			Microbial Contamination	Low Risk	Vicinity not clean	Protected Water Source				
HDW17			Microbial Contamination	Low Risk	Vicinity not clean	Protected Water Source				
HDW18			Microbial Contamination	Low Risk	Vicinity not clean	Protected Water Source				
HDW19			Microbial Contamination	Low Risk	Pit latrine within the source	Protected Water Source				
HDW20			Microbial Contamination	Low Risk	Vicinity not clean	Protected Water Source				

Table 4.19: Hazard Event–Well head not Water Tight

ɀard ɜnt	Water source	Associated Hazard	Cause	Risk	Critical Limits		Corrective Action	Monitoring		
					Current Situation	Target		What	When	Who
	HDW_1									
	HDW_2									
	HDW_3									
	HDW_4									
	HDW_5									
	HDW_6									
ll ɪ	HDW_7									
	HDW_8			High Risk		Protected Water Source				
er t	HDW_9		Use of rope and bucket for abstraction							
	HDW_{10}	Surface Water Intrusion						Protection of Well		
	HDW_{11}									
	HDW_{12}				Use of rope and bucket for abstraction		Install hand pump on water source			
	HDW_{13}								Bi-annually	
	HDW_{14}									
	HDW_{15}									
	HDW_{16}									
	HDW_{17}									
	HDW_{18}									Designated Personnel
	HDW_{19}									
	HDW_{20}									

Table 4.20: Hazard Event– Flooding around water source

Hazard Event	Water source	Associated Hazard	Cause	Risk	Critical Limits		Corrective Action	Monitoring		
					Current Situation	Target		What	When	Who
Flooding around water source	HDW_1	Water Quality Compromised	Not Applicable	No Observed Risk	Protected Well	Protected Water Source	None			
	HDW_2									
	HDW_3									
	HDW_4									
	HDW_5									
	HDW_6									
	HDW_7									
	HDW_8									
	HDW_9									
	HDW_{10}									
	HDW_{11}									
	HDW_{12}									
	HDW_{13}									
	HDW_{14}									
	HDW_{15}									
	HDW_{16}									
	HDW_{17}									
	HDW_{18}									
	HDW_{19}									
	HDW_{20}									

4.3.1 Hazard Analysis Discussion

4.3.1.1 Poor Water Quality

Water source 1, 2 and 3 of the twenty water sources monitored met all the requirements for drinking water, corrective measured were proffered for the seventeen sources as seen in table 4.17.

4.3.1.2 Septic Tank Location

All the water sources met the minimum requirement of a distance of at least 30m from a septic tank location except for water sources 11, 13 and 19 where the distance is not up to 30m.

4.3.1.3 Well head not Water Tight

Water sources 5 and 10 are not well covered. All water source has unprotected well head tight and corrective measured were proffered as seen in table 4.19.

4.3.1.4 Flooding around water source

All the twenty water sources were not located in flood zones as analyze in table 4.20

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the research, it was found that:

i. The pH of sample 1,2,3,4,5,10,15 and 16 are below acceptable limit
ii. The magnesium content of all samples was above NSDWQ recommended limit.
iii. The total hardness of all water samples were within acceptable limit
iv. The total dissolve solid of all samples were within acceptable limit
v. The total coliform count of all water samples except sample 1, 2 and 3 were above acceptable limit. The shows the samples were contaminated
vi. Hazard Analysis proffered corrective measures for water sources with high risks
vii. Sanitation around all domestic water source requires improvement to eliminate possibility of contamination of water from the source.

5.2 Recommendation

It is recommended that;

1. The pH of water samples that are below acceptable limit can be increased by using neutralizing filters through the addition of neutralizing materials.
2. The magnesium content of water sample can be reduce using Packaged water softener.
3. The water source can be decontaminated by chlorination.
4. Regular monitoring of domestic water quality should be maintained for all the domestic water sources.
5. Strict adherence to basic environmental sanitation rules should be observed around all the domestic water sources.

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