CERTIFICATION

This is to certify that this is an original and independent research project carried out by Afun, T. O. (WMA/12/0485) in the department of Water Resources Management and Agro-meteorology, in partial fulfillment of the requirements for the award of bachelor in water resources management and agro-meteorlogy degree of the Federal University Oye-Ekiti, Ekiti State, Nigeria.

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DEDICATION

The piece of this work is dedicated to the almighty God for seeing me through the course of my study.

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I am grateful to God almighty for the grace, strength, knowledge and wisdom granted me in undertaking this research. I would like to express my sincerest gratitude to my supervisor Mr Joseph A. Adeyeye for his advice, thoughtful suggestions and understanding. His intellectual inspirations and encouragement were very helpful in my whole period of research.

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God bless you all in Jesus name.

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ABSTRACT

The study investigated the sanitary assessment and physiochemical characteristics of hand-dug wells in Ado-Ekiti, Ekiti State, Nigeria with a view to support the operation and maintenance of hand-dug wells by providing clear guidance for remedial action to protect and improve water supply in the study area. The town was zoned into ten areas and 50 wells were randomly selected for sanitary risk assessment using the sanitary inspection forms and ten water samples were collected from the zones and tested for microbial and physiochemical parameters. The microbial parameters tested for were: total coliform count, faecal streptococci and E. coli, while the physiochemical parameters were: colour, turbidity, pH, temperature, sulphate (SO_4^{2-}), nitrate (NO_3^-), iron (Fe^{+2}), fluoride (F^-), chloride (Cl^-), sodium (Na^+), calcium (Ca^{+2}), potassium (K^+), magnesium (Mg^{+2}), manganese (Mn^{+2}), total dissolved solids, conductivity, alkalinity and hardness. The wells were found to be at various levels of risk: about 52% were moderately at risk, 22% were at high risk while about 4% were at very high risk of contamination. All the samples from the private hand-dug wells tested positive to total coliform count, E. coli were present in 90% of the water samples while 70% tested positive to faecal streptococci. The physiochemical parameters of the well waters were compared with the guidelines set by the World Health Organization (WHO) and the Nigerian Standards for Drinking Water Quality (NSDWQ), and calcium, iron, pH, alkalinity and manganese were found not to be in conformity with permissible limits.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Every living creature needs water to survive on this earth and just as the saying goes, 'water is life' so is it true for the continuance of nature itself. Water is needed not only for biological processes, but for physico-chemical processes as well. Water has no substitute, so the more the growth in population, the more the demand placed on water. It is necessary therefore to ensure that the water been used for various purposes such as domestic, municipal, industrial, etc., are of standard quality. According to WHO (2006), about 1.1 billion people do not have access to improved drinking water supply and a larger part of this estimate was found in the developing countries. In most cities, towns and villages in Nigeria, valuable man-hours are spent on seeking and fetching water, often of doubtful quality from distant sources (Efe, 2005). These problems of acute water supply have resulted in the rapid increase in hand dug wells and boreholes with some located within the proximity of dung sites, soak-away and pit latrines.

Portable water is precious, we cannot live without it and human activities have profound impact on the quality and quantity of water available. Domestic water is used for drinking, cooking, bathing and cleaning, however, access to safe drinking and sanitation is critical in terms of health. For instance, unsafe drinking water contributed to numerous health problems in developing countries such as the one billion or more incidents of diarrhoea that occur annually (Annan, 2003).

Groundwater can become contaminated from natural sources or numerous types of human activities. Waste from residential, commercial, industrial and agricultural activities can seriously affect groundwater quality. These contaminants may reach groundwater from activities on the land surface, such as industrial waste storage or spills; from sources below the land surface but above the water table, such as septic systems, disposal of hazardous materials, chemical storage and spills, landfills, sewage lagoons, sewers and other pipelines, pesticide and fertilizer use; from structures beneath the water table, such as wells, or from contaminated recharge from the aquifers.

Due to the increase in population of Ado-Ekiti over the last twenty years, from 156,122 in year 1991 to 308,621 in the year 2006 population census conducted, many wells have been exposed to sanitary-risk factors which may threaten the quality of the water since most of the drinking water which is being utilized in the city are normally due to less attention to environmental essentials. It is in this regard that technical assessments such as sanitary survey to demonstrate the level of the risk to the consumers of these wells are therefore very important.

Improperly abandoned wells act as a conduit through which contaminants can reach an aquifer. Some people use abandoned wells to dispose of wastes. These wells may contaminate aquifers, which supply water to municipal wells. In addition, abandoned exploratory wells, test wells, and geotechnical boreholes, if not properly protected and covered, are potential conduits for contamination (www.google.com, 2003).

Active wells can also be poorly constructed resulting in groundwater contamination. Poor casings, inadequate covers, or lack of concrete pads, may allow contaminated surface water into the well. Older wells are more prone to construction problems as they were constructed prior to established standards and regulations guiding well drillers in their construction. Other types of wells that may be sources of contamination are "dry wells" and sumps that collect storm water runoff and spilled liquids, drainage wells, which are used in wet areas to remove water and transport it into deeper soils and poorly constructed irrigation wells.

Hand-dug wells could be protected, un-protected or semi-protected. A protected well is one equipped with a dedicated pump (manual or motorised), concrete lining and platform (or apron), head wall, cover and drainage channel (Murcott, 2007; Oluwasanya et al., 2011). Unprotected well is without any of the features stated above and a semi-protected well may have one or more of the features found in a protected well (Oluwasanya et al., 2011).

1.2 STATEMENT OF PROBLEM

It is a good thing to experience growth in a community because increase in the size of the population can bring about development, but availability of safe and reliable source of water is an essential prerequisite for sustained development. It is in this regard that the assessment of the water (ground water), in particular the hand dug wells is important.

1.3 SCOPE OF THE STUDY

The scope of this research is based on providing information through Sanitary risk assessment and determination of physiochemical and bacteriological characteristics of hand dug wells in Ado-Ekiti, the Ekiti state capital. Structured questionnaire were used to elicit information of Hand dug wells condition while laboratory analysis was used water parameter determination.

1.4 LIMITATIONS

Usually, the metropolis has numerous hand dug wells and boreholes which make this research work restricted to the randomly selected hand dug wells to represent the study area. This choice is due to the financial constraint that is experienced in carrying out analysis of water samples gotten from the different sources for the whole city. The research work is also limited to the use of sanitary assessment form (questionnaires) and laboratory analysis carried out on water samples to obtain results.

1.5 SIGNIFICANCE OF STUDY

The significance of the study is to:

1. To support the operation and maintenance of hand-dug wells by providing clear guidance for remedial action to protect and improve water supply.
2. To enlighten the inhabitants on the nessecity of sanitary assessment of hand dug wells
3. To serve as guide for further ground water projects of the environment.

1.6 AIM

The general aim of this study is to investigate the sanitary conditions and the characteristics of the hand dug wells in Ado-Ekiti.

1.7 SPECIFIC OBJECTIVES

1. To evaluate the sanitary conditions of the hand dug-wells in the study area.
2. To determine the physico-chemical and microbiological characteristics of the water in relation to the assessment.
3. To determine the suitability of the well water for drinking purposes.

CHAPTERTWO

LITERATURE REVIEW

2.1 GROUNDWATER

Ground water is the water beneath the surface of the ground in the zone of saturation where every pore space between rock and soil particles is saturated with water. Above the zone of saturation is an area where both air and moisture are found in the spaces between soil and rock particles called the zone of aeration.

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

One of the most dependent sources of water supply in developing coutries has been groundwater. And there is no doubt that sanitation choice of interest for such communities is on-site sanitation (AGROSS, 2001).

2.1.1 ACCESSING THE GROUNDWATER

It is well known that, in its natural state, groundwater is usually of good microbiological quality and as a result is often the preferred source of drinking water supply as treatment is limited to disinfection. In the case of rural and peri-urban supplies, groundwater supplies are usually untreated. It is known that accessing groundwater for drinking purpose is through the following:

- Boreholes (also known as tube wells)—These are narrow-diameter, drilled holes that can be shallow or deep, and use a hand pump or motorized or electric submersible pump to abstract water. Boreholes are often easier to protect from pollution than other groundwater supplies.
- Dug wells—these are usually dug by hand and are typically of large diameter and of relatively shallow depth. These may be fitted with a hand pump or some other form of

improved water collection or buckets and ropes utilized. Dug wells are susceptible to contamination, especially where they are shallow and/or uncovered.

- Springs—these may occur where groundwater discharges at the surface. They are generally protected by constructing a spring box around the eye of the spring and may feed piped systems by gravity. Springs can be susceptible to contamination and great care needs to be taken to protect the supply (ARGOSS, 2001).

2.2. GROUNDWATER QUALITY

According to Kolo (2009), groundwater usage is based on the postulation that groundwater, being precluded from the atmosphere, is less susceptible to pollution. However, groundwater is sometimes known to be vulnerable to quality problems that may have serious impact on human health. But water, which is the most precious natural, needed for life after oxygen and "key" to health, should be qualitative before being used (Umara et al 2007). The quality of water varies with its purpose, thus the quality required for it is therefore affected by Landfill of solid wastes from domestic, industrial and irrigation purposes. Polluted waters, irrespective of the pollutants, when consumed, may lead to variety of diseases, such as cholera, typhoid, dysentery, skin and mental disorders, etc.

To safeguard the health of people and to reduce to the barest minimum of ugly experiences of drinking and/or using of low quality waters, it is necessary that the quality of water should be monitored with the view to finding lasting solution to health problems associated with the use and drinking of low quality waters. Both liquid and solid wastes materials dumped either on soil surface or buried are known to decompose to produce leachate that penetrate aquifers and contaminate the groundwater thereby raising the potential toxicity of the water to consumers. Burying and surface dumping of both industrial and domestic waste are nowadays a common practice among rural and urban dwellers.

The quality of groundwater however, principally depends on the element(s) present in it while seeping down. The world health organization WHO has set a quality guideline for drinking water and recommends that the properties of every drinking water should fall within the acceptable limit set by it.

Generally, the closer the groundwater is to the surface, the more influential is the effect of heavy rain in carrying bacteria and other organisms through the soil into it. Poorly made concrete apron and water run-off can crack, and will allow leakage of waste water from the surface back into the well to contaminate it. Buckets and ropes which are used to raise the water, and often lie around the unhygienic rim of the well also pollute the water. Generally, shallow wells are less than 15 m deep (Appiah and Momende, 2010). Currently, the most practical approach to the problem of improving and maintaining the quality of water delivered in rural water supply schemes is not to impose a set standard, but to insist on adequate measures of sanitary protection which significantly improve the quality of water (Appiah and Momende, 2010).

2.3 FACTORS INFLUENCING THE QUALITY OF THE GROUNDWATER

2.3.1. GEOLOGY

2.3.1.1 Nature of Aquifer

The quality of groundwater may be affected by the source rock, soil composition, or overlaying superficial deposits. Chemical reactions between ions in the water and minerals in associated rocks also play a role in this regard. The rate of movement of groundwater and human activity within the catchment basin may also affect the water quality (Appiah and Momende, 2010). Although there are many types of rocks that permit significant quantities of water to be abstracted (aquifer), these can be summarized into a number of broad groups that takes into account not only the rock type but also the environment in which the rocks were formed. These are - the unconsolidated aquifers which are rarely simple systems that are typically layered, with permeable layers of sands and gravel separated by less permeable layers of clay or silt, producing complex groundwater flow patterns. Groundwater in these aquifers is naturally of excellent microbiological quality; the second is the consolidated sedimentary aquifers. This include; the consolidated sediments and coastal limestone. The Consolidated sediments are younger sandstones which usually retain a primary porosity (the porosity between grains) and are typically of low-moderate permeability. In older, more-cemented formations, the primary porosity is virtually absent and it is the secondary (fracture) porosity which provides the aquifer permeability and storage. The vulnerability to pollution of consolidated sedimentary aquifers is greatly increased by the development of secondary permeability, especially in the karst limestone where particularly rapid water movement along fractures is possible. These characteristics have important implications for groundwater quality. Water movement from the soil to the water-table is often via fractures and is so rapid that even filtration and removal of micro-organisms within the unsaturated zone is not effective. Consequently these formations are extremely vulnerable to widespread pollution.

The third aquifer group is the weathered basement aquifers. Over large areas of Africa and parts of Asia, groundwater occurs in basement rock aquifers. These aquifers are often ancient, the aquifer can be considered to have relatively low pollution vulnerability. However, there are other areas where the weathered layer is of variable thickness and basement rock can occur at the ground surface. Such aquifer environments are more vulnerable to pollution because of the likelihood of fractures extending close to ground surface (ARGOSS, 2001).

2.3.1.2 The Vulnerability of Aquifer to Pollution and Risks to Groundwater Supplies

According to the British Geological Survey commissioned report (ARGOSS, 2001) the term aquifer pollution vulnerability is used to represent the intrinsic characteristics of the aquifer which determine whether it is likely to be affected by an imposed contaminant load. Vulnerability assessment is based on the likely travel time for water to move from the ground surface to the water table – the greater the travel time the greater the opportunity for contaminant attenuation. As water moves through the ground, natural processes reduce (or attenuate) the concentration of many contaminants including harmful microorganisms. The degree to which attenuation occurs is dependent on the type of soil and rock, the types of contaminant and the associated activity.

2.3.2. ON-SITE SANITATION SYSTEMS

On-site sanitation systems, which include septic tanks and all forms of pit latrine, store wastes at the point of disposal. Septic tanks typically hold the solids compartment of wastes in a sealed tank where the matter decomposes anaerobically; the liquid effluent is usually discharged into a soak-away. Pit latrines are generally not sealed and are usually only appropriate where the level of water table is low (communal or yard) and minimal liquid volumes are generated (ARGOSS, 2001). Whilst the absence of water and sanitation facilities is associated with high rates of disease incidence and infant mortality rates, improvements in sanitation need to be integrated and properly planned; otherwise one unanticipated outcome may be the contamination of drinking water by faecal matter derived from on-site sanitation (ARGOSS, 2001).The principal hazard from on-site sanitation is the risk of transmission of pathogenic micro-organisms. Concentrations of nitrate in excess of the WHO (2008) guideline limit can give rise to methemoglobinemia (or blue-baby syndrome) (Appiah and Momende, 2010). In some geological settings elevated groundwater concentrations of some trace elements e.g. arsenic, fluorine, manganese can pose a health hazard (Appiah and Momende, 2010).

On-site sanitation systems naturally raise a concern about the pollution of groundwater. Van Ryneveld *et al.*, (1997), wrote that pollution from on-site sanitation is influenced by a variety of complex factors namely:

- Varying subsurface conditions: - In addition to the variety of subsurface soils encountered, within any soil the most critical distinction is between the saturated and the unsaturated zone. Sudhakar (2011) also wrote that unsaturated zone is most important line of defence against faecal pollution of aquifer as it is less permeable
- Varying contaminants:- Different contaminants have different characteristics (e.g. mobility and persistence) which are affected differently by conditions in the subsurface and
- Varying mechanisms of movement through different materials and which vary with scale. Bacteria travel depends on velocity of groundwater flow. During travel, fraction die or retained (adsorbed or screened) on soil matrix. The key factors for removal of bacteria and viruses from groundwater are effluent residence time between contamination source and point of water abstraction. The probable survival time for coliforms in anaerobic groundwater environment is 4-7 days (Sudhakar, 2011).

2.3.3 IMPACT OF POOR SOLID WASTE MANAGEMENT ON GROUNDWATER QUALITY

The leachate produced by waste disposal sites contains a large amount of substances which are likely to contaminate groundwater. A study conducted in India to look at the impact of poor solid waste management on groundwater has revealed that the groundwater quality does not conform to the drinking water quality standards as per Bureau of Indian Standards (Vansanthi, 2008). The effects of dumping activity on groundwater appeared most clearly as high concentrations of total dissolved solids, electrical conductivity, total hardness, chlorides, chemical oxygen demand, nitrates and sulphates. Leachate collected from the site showed presence of heavy metals (Vansanthi, 2008).

2.3.4 EFFECT OF DISTANCE FROM POLLUTION SOURCE ON GROUNDWATER QUALITY

Available literature maintains that increased lateral separation between pollution source and groundwater supply reduces the risk of faecal pollution. Hence, the farther a groundwater supply is from the pollution source the less the risk of pollution (ARGOSS, 2001). Odai and Dugbantey (2003) studied the concentration of selected contaminants in relation to the distances between the groundwater supplies and the on-site sanitation systems. The contaminants analysed were faecal coliform, nitrate, and chloride because they are key indicators of the presence of faecal pollution. The results were that the levels of faecal coliform were highest in the wells at distances 25m and 46m, respectively from on-site sanitation. The well at a distance of 49m away from a pit latrine, was however, less polluted. With respect to nitrate and chloride, they found that the trend for concentration of the three contaminants was similar: the closer the well to pollution sources the higher the levels of concentration of the three contaminants. Odai and Dugbantey (2003) therefore concluded that the pollution levels in groundwater sources depend on distance between the groundwater supplies and the pit latrines. They also indicated that because the latrines and groundwater supplies were located in different communities with varying soil types, it is likely that the low levels of contaminant levels at some distances may be due to the soil types. Their second speculation was that there may be ingress of faecal coliform into the well through the openings.

2.3.5 EFFECT OF ROCK BEARING STRATA ON GROUNDWATER QUALITY

Atmospheric precipitation infiltrating through the soil dissolves $C0_2$ produced by biological activity. The resulting solution of weak carbonic acid dissolves soluble minerals from the underlying rock. A second process operating during passage through the soil is the consumption by soil organisms of the oxygen which was dissolved in the rainfall. These reactions occur in the soil and the top few metres of the underlying rock. Groundwater in the outcrop areas of aquifers is likely to be low in overall mineralization, with the natural constituents depending on the materials of which the rocks are made (Chilton, 1996).

In igneous rocks, the restricted opportunity for reactions to take place is single out by the fact that groundwater storage and flow is predominantly in fissures, giving short residence times and low contact surface area. Groundwater in igneous rocks is, therefore often exceptionally lightly mineralized, although characterized by high silica contents (Hem, 1989). Pure siliceous sands or sandstones without soluble cement also contain ground-water with very low total dissolved solids (Matthess, 1982). In such aquifers, the dissolved constituents that are present come mainly from other sources, such as rainfall and dry deposition, especially sodium, chloride and sulphate which, in coastal regions, may exceed calcium, magnesium and bicarbonate. Sulphate may also be produced by the oxidation of metallic sulphides which are present in small amounts in many rock types. The presence of soluble cement may produce increased concentrations of the major ions. Ground-waters in carbonate rocks have pH values above 7, and mineral contents usually dominated by bicarbonate and calcium. In many small and/or shallow aquifers the hydrochemistry does not evolve further. It, however, an aquifer dips below a confining layer, a sequence of hydro-chemical processes occurs with progressive distance down gradient from the outcrop.

2.4 MEASURING WATER QUALITY

The quantitative physiochemical and microbial analysis of the hand dug wells was carried out in the month of April, 2017.

2.4.1 MICROBIOLOGICAL PARAMETERS

The microbiological agents in water can include bacteria, protozoan, and viruses. The microbiological contaminants are classified as primary drinking water standards, because of specific health concerns and the spread of disease. Because the cost for testing for specific microbiological agents may be cost prohibitive, most drinking water standards use coliform bacteria as an indicator of contamination (Brian, 2012). The World Health Organization (2008) has defined coliforms as any rod shaped, non-spore-forming, gram-negative bacteria capable of growth in the presence of bile salts or other surface-active agents.

- ***Total Coliform*** – These bacteria can be easily tested by certified laboratories and can be used as an indicator of the microbiological quality of your water. If these bacteria are not present in your water, i.e., a result of absent or < 1 colony per 100 ml, this is interpreted to mean that it is not likely that the water contains a microbiological agent that may pose a health problem. If the bacteria are present in your water, i.e., a result of Present or 1 or more colonies per 100 ml, this is interpreted to mean that it is more likely that the water contains a microbiological agent that may pose a health problem and that some action is needed (Brian, 2012).
- **Faecal Coliform** - This is a sub-group of total coliform bacteria which are more typically found in the waste of warm-blooded animals, but which can be found in non-mammals and insects. Faecal coliform bacteria should not be present in drinking water and a suitable result would be Absent or < 1 colony per 100 ml.
- ***Escherichia coli (E.coli.)***- This is a bacterial strain that is most commonly found in humans and animals. The best coliform indicator of faecal contamination from human and animal waste is *E. coli.* In human and animal faeces, 90 to 100% of the coliform organisms isolated are *E. coli.* In sewage and contaminated water samples, the percentage drops to 59%.The presence of this group of bacteria would suggest the source is a human or mammalian waste source and a suitable result would be Absent or < 1 colony per 100 ml (American Public Health Association, 1992). Brian (2012) wrote that if the results suggest that total coliform bacteria, faecal coliform, and/or *E.coli* are present this would mean that it is more likely that a pathogen is present in the water.

2.4.2 PHYSICO-CHEMICAL PARAMETERS

- **Turbidity** - Turbidity in water is caused by the presence of particulate matter such as clay, silt, colloidal particles, and microorganisms. Turbidity is the measure of the water's ability to scatter and absorb light. High turbidity levels can reduce the efficiency of disinfection by creating a disinfection demand. The particles may also provide absorption sites for toxic substances in the water. Although it does not adversely affect human health, turbidity is an important parameter in that it can protect microorganisms from disinfection effects, can stimulate bacteria growth and indicates problems with treatment processes (WHO, 2004).Turbidity is measured in Nephelometric Turbidity Units (NTU), using a turbidity meter (USEPA, 1995). For effective disinfection, median turbidity should be below 0.1 NTU although turbidity of less than 5NTU is usually acceptable to consumers (WHO, 2004).

- **Temperature** - Depending on whether temperature is high or low, may affect other parameters including conductivity and dissolved minerals. It affects the reaction rates and solubility levels of chemicals present in water. It is determined using Temperature meter (Hach, 2000). Cool water is generally more palatable than warm water.

- **Conductivity** - Conductivity is a measure of the water's ability to conduct electric current. It is directly related to the total dissolved salt content of the water. This is so because the salts dissociate into positive and negative ions and can conduct electric current proportional to their concentration. It is recorded in micro Siemens per centimetre (µS/cm) using a conductivity meter (Hach, 2000).Human activities may influence conductivity. Sewage and farm runoff can raise conductivity due to the presence of nitrate and phosphate. Runoff from roads can also carry salt and other materials that contribute ions to water. WHO (2006) recommended level for conductivity is 300µS/cm for drinking water.

- **pH** - It is the measure of acidity or alkalinity of the water. The pH of most drinking water lies within the range of 6.5 – 8.5 (WHO, 2004). Usually it has no direct impact on consumers and it is one of the most important operational water quality parameters (WHO, 2006). The usual pH for fresh water aquatic system is 6 to 9.Waters around this pH range is an indicator of existence of biological life in them as most of living organisms thrive in a quite narrow and critical pH range. The pH of water is related in several different ways to almost every other water quality parameter, as aqueous chemical equilibriums invariably involve hydrogen ions, (WHO, 2006).Water sample with low pH attributed to discharge of acidic water into these sources by agricultural and domestic activities. In fact, 98% of all world groundwater are dominated by Ca_2^- and HCO_3^- due to limestone weathering in the catchments and under groundwater beds (Brian, 2012).

❖ **Total Dissolved Solids (TDS)** - Total Dissolved Solid (TDS) is a measure of the total amount of dissolved substances in the water sample. It is not a direct measure of a specific element or contaminant. An elevated TDS may be associated with an elevated water hardness, chemical deposits, corrosion by-products, staining, or salty bitter tastes. If the TDS content of the water is high, the primary recommendation would be to test the water for additional parameters, such as: total hardness, iron, manganese, sodium, chloride, sulphate, alkalinity, and nitrate, to determine the nature of the water quality problem. According to WHO (2006), there has not been any deleterious physiological reactions occurring in persons consuming drinking water that have TDS values in excess of 1000mg/l. WHO, however, recommends the low level of the latter as a guideline value for TDS. Kempster *et al.* (1997) reported a critical TDS value of 2450 mg/l above which some long term health problems might be anticipated due to excessive concentrations of dissolved particles in drinking water.

❖ **Total Suspended Solid** - Total Suspended Solids (TSS) can include algal matter or non-algal matter such as finely ground calcium carbonate particles from limestone. Depending on the source, these substances may impact any number of colours to the water.

❖ **Nitrate** - Nitrate (NO_3^-) is water-soluble and is made up of nitrogen and oxygen. It is formed when nitrogen from ammonia or other sources combines with oxygenated water. Water naturally, contains less than 1 mg nitrate/nitrogen per litre and is not a major source of exposure. Higher levels indicate that the water has been contaminated. The USEPA, Minimum Concentration Level is 10 mg NO_3^-N/L for nitrate and 1 mg NO_2^- N/L for nitrite (Brian, 2012). The primary source of nitrate and nitrite would be agricultural runoff, poorly maintained septic systems, sewage disposal, and acid solutions in injection fluids, urban runoff, and natural deposits. Due to potential toxicity and widespread occurrence in water, it is regulated and should not exceed 10 mg/l in drinking water (WHO, 2006). The primary concern for nitrate and nitrite is that infants less than 6 months are susceptible to blue-baby syndrome, which is potentially fatal if not treated.

❖ **Iron** - Iron occurs in groundwater in high concentrations in many places. It is generally associated with acidic groundwater or anaerobic (oxygen-free) groundwater. The Secondary Maximum Contaminant Level (SMCL) for iron is 0.3 mg/l (Brian, 2012). Iron in the water can be associated with a bitter/metallic taste, formation of sediment and yellow, red, and orange films, and discoloured clothing during washing (Brian, 2012). Staining of laundry and household fixtures can occur in waters with high iron concentration.

❖ **Sodium** - According to WHO (2003), Sodium salts are generally highly soluble in water and are leached from the terrestrial environment to groundwater and surface water. They are non-volatile and will thus be found in the atmosphere only in association with particulate matter. The sodium ion is ubiquitous in water. Most water supplies contain less than 20 mg of sodium per litre, but in some countries levels can exceed 250 mg/litre. Saline intrusion, mineral deposits, seawater spray, sewage effluents, and salt used in road de-icing can all contribute significant quantities of sodium to water. In addition, water-treatment chemicals, such as sodium fluoride, sodium bicarbonate, and sodium hypochlorite, can together result in sodium levels as high as 30 mg/litre. Domestic water softeners can give levels of over 300 mg/litre, but much lower ones are usually found (EURO Reports, 1978).

Although it is generally agreed that sodium is essential to human life, there is no agreement on the minimum daily requirement. However, it has been estimated by the National Research Council (Washington, DC, National Academy Press, 1989), that a total daily intake of 120–400 mg will meet the daily needs of growing infants and young children, and 500 mg those of adults.

Sodium concentrations can be determined by direct aspiration atomic absorption spectroscopy (Andreae *et al*, 1981).

- **Fluoride**

It occurs naturally in most soils and in many water supplies. A UV-Visible spectrophotometer is used to determine fluoride ion concentration in water (Craun *et al.*, 2003). The Maximum Contaminant Level (MCL) for fluoride is 4 mg/L, but because of the potential for dental fluorosis, i.e., mottled or discoloured teeth, the USEPA has set a secondary standard of 2 mg/l (Brian, 2012). Elevated levels of fluoride have been shown to cause bone disease. Low levels of fluoride may help to prevent cavities in teeth (WHO, 2008).

- **Chloride**

Chloride is present in all potable water supplies and in sewage usually as a metallic salt. The USEPA Secondary Maximum Contaminant Level (SMCL) and the WHO guideline value for chloride is 250 mg/l. The standard has been set because of potential aesthetic problems associated with the taste of the water and that elevated levels can facilitate the corrosion of piping and fixtures (Brian, 2012). Chlorides are found naturally in the environment, but elevated levels of chloride can also be associated with septic system effluent, storm water runoff, brine water, cleaning solutions, and other industrial solutions. Its concentration in water is determined using precipitation titration (Hach, 2000; WHO, 2006).

❖ Total Hardness

Total hardness in water is caused by dissolved calcium and, to a lesser extent, magnesium salts. The hardness of the water is reported as the equivalent concentration of calcium carbonate ($CaCO_3$) per litre of water, but the actual test measures the calcium, magnesium, manganese, iron, and other multivalent positively charged ions. Individuals typically report aesthetic problems with the water when the total hardness is above 160 mg $CaCO_3$/l, but it is possible that corrosion problems could be associated with water with very low water hardness (Brain, 2012). Depending on pH and alkalinity, hardness above 200 mg/l can result in scale deposition, particularly on heating. It is determined by titration with EDTA (Ethylene diamine tetra-acetic acid) (WHO, 2006). Water with less than 75 mg/l $CaCO_3$ is considered to be soft and above 150 mg/l as hard.

❖ Sulphate

According to USEPA (1995) the Secondary Maximum Contaminant Level for sulphate is 250 mg/l. At a level of 250 mg/l, sulphate can impart a bitter to salty taste to the water, but at a level of over 500 mg/l the sulphate can have a laxative effect (Brian, 2012).

Sulphate is found in natural waters in a wide range of concentrations. A Spectrophotometer is used to determined sulphate concentration in drinking water (Hach, 2000). Sulphates may also be associated with the presence of hydrogen sulphide or rotten egg odours to the water. A hydrogen sulphide odour could be caused by a combination of chemical or biological reactions. There is no specific drinking water standard for hydrogen sulphide, but there is a secondary drinking water standard for odour.

❖ Phosphates

High concentration of phosphate in water bodies is an indication of pollution and largely responsible for eutrophication (Appiah and Momende, 2010).Phosphates are not toxic to people or animals unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphate (Brian, 2012). WHO (2006), set a maximum contaminant level at 0.3mg/l. Phosphorus is normally low (< 1 mg/L) in clean potable water sources and usually not regulated (Nduka *et al.*, 2008).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 STUDY AREA

Ado-Ekiti is the state capital of Ekiti state, located in the south western part of Nigeria. The population in 2006 was 308,621. The people of Ado-Ekiti are mainly of the Ekiti sub-ethnic group of the Yoruba. Various commercial enterprises operate in Ado-Ekiti. The city is the trade centre for a farming region where yams, cassava, grain,and tobacco are grown. Ado-Ekiti is located within longitudes 5°00′E and 5°15′E and latitudes 7°30′N and 7°45′N, covering an area of 1,471.5 km^2, on a low-land surrounded by several isolated hills and inselbergs. The average annual temperature in Ado-Ekiti is 25.1°C, average precipitation is 1334mm. precipitation is lowest in January, with an average of 9mm. most precipitation falls in September, with an average of 235mm. march is the hottest month at an average temperature of 27.1°C. The average temperature is lowest in August at 22.9°C. The topography of the area is rugged due to the presence of crystalline basement rocks like charnockite and quartzite ridges which rise abruptly above the surrounding country rocks. The area is underlain by the Precambrian basement complex rocks of south western Nigeria and drained by River Ireje, Elemi, Omisanjana and Awedele Stream. They flow into River Ose and River Owena and empty into the Atlantic Ocean (Rahaman, 1988).

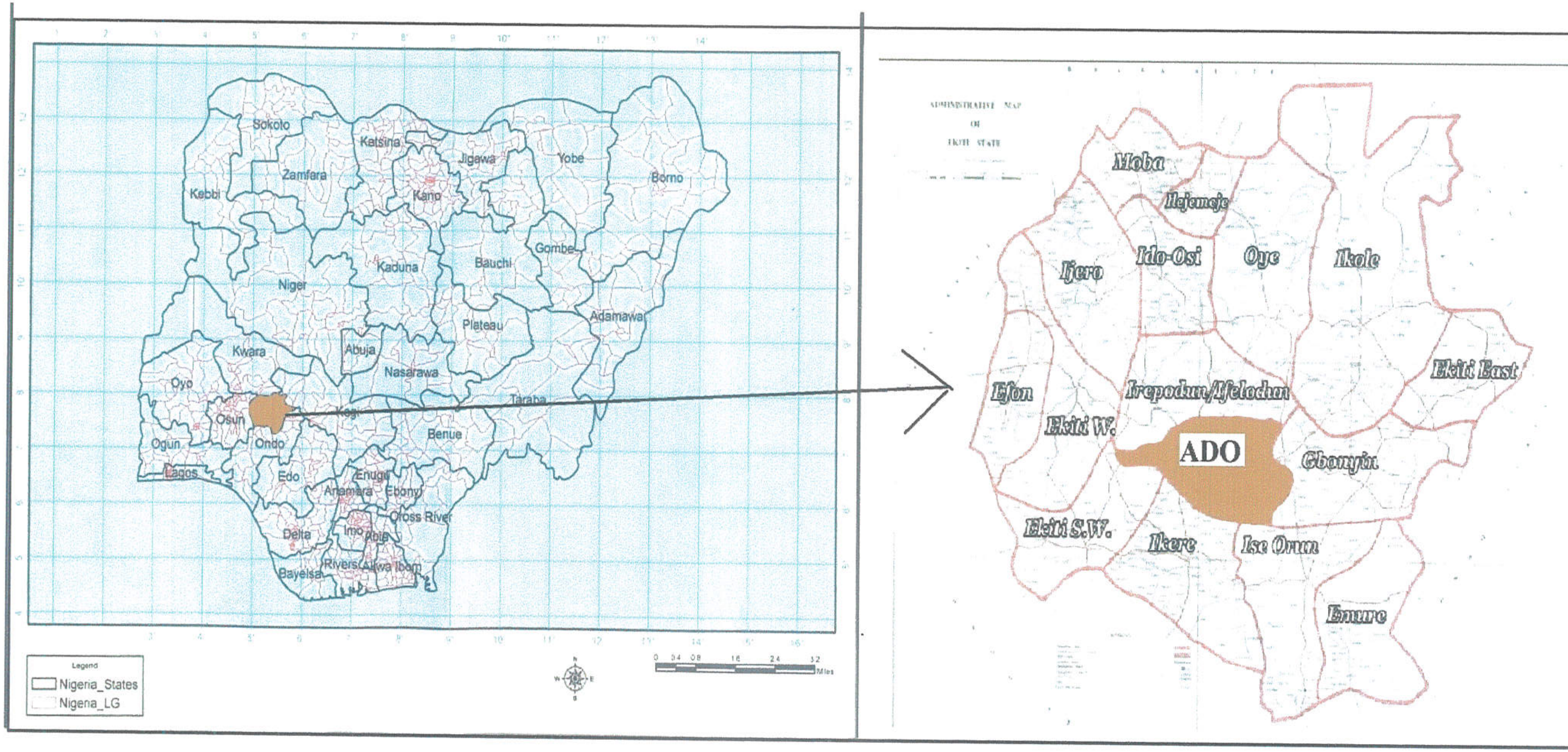

Figure 1: Map of Nigeria Showing Ekiti State and the Study Area

Source: Google, (2012)

Figure 2: Google Map Showing the Water Sampling Points

Table 1: GPS coordinates and the sampling point's elevation above sea level

Wells	Longitude (E)	Latitude (N)	ELEVATION (m)
Oke-ila	$005^{0}13.643'$	$07^{0}38.356'$	1345
Adebayo	$005^{0}13.675'$	$07^{0}39.375'$	1275
Basiri	$005^{0}12.704'$	$07^{0}39.149'$	1352
Omisanjana	$005^{0}11.986'$	$07^{0}36.143'$	1376
Poly	$005^{0}17.773'$	$07^{0}35.591'$	1242
Mattew	$005^{0}13.628'$	$07^{0}36.890'$	1425
Ajilosun	$005^{0}13.376'$	$07^{0}36.621'$	1384
Isato	$005^{0}13.151'$	$07^{0}37.149'$	1419
Falegan	$005^{0}11.532'$	$07^{0}37.198'$	1455
Aba-Erinfun	$005^{0}16.453'$	$07^{0}36.689'$	1365

3.2 MATERIALS AND EQUIPMENTS

- Sanitary assessment forms
- GPS
- pH meter
- E.C meter
- Turbidity meter
- Sample bottles
- Sample storage containers
- Ice packs
- Label markers

3.3 METHODOLOGY

3.3.1 SANITARY SURVEY

The selections of these areas were based on population, activities, and accessibility. Fifty Hand-dug wells were assessed for sanitary conditions and water sample was taken for physiochemical characterization for each zone.

A cross-sectional sanitary assessment was carried out. This is an assessment of the potential sources of contamination which include the state of the infrastructure and protection works of the well that may affect the quality of water supply from the hand dug wells. A systematic approach was taken by using a standardised sanitary inspection format recommended by the WHO, (1996) as seen in APPENDIX 1. The procedure involved completing a 10-point standardised data form with a series of questions with a 'yes' and 'no' options for designated risks. A score of one point was awarded for each 'yes' answer (risk observed) and zero point for each 'no' answer (no risk observed). By summing all —yes scores, a final risk score was obtained, which provided the overall assessment of the risk profile of each well assessed.

The total sanitary risk score was converted to a percentage. The aggregate risk score was graded as very high (81 to 100%), high (51 to 80%), medium (31 to 50%) and (0 to 30%) as low. This aggregate scoring is in line with WHO (2010) systematic approach of obtaining quantitative value from the standardised sanitary inspection.

In assessing the wells for the sanitary conditions, seven wells were assessed each in Adebayo, Odo-Ado, Oke-ila, and Falegan; five wells each in Basiri and Omisanjana; four wells each in, Isato, and Ajilosun; three wells at Poly; and a well which is the only hand dug well at Aba-Erinfun.

The WHO (1996) established format for sanitary inspection forms consist of factors used to assess the sanitary risk of any groundwater source may involve some or all of the following:

- The proximity of latrines within 10m of the facility
- An animal, human waste or refuse dump within 10m of the facility
- Presence of animal breeding within 30m of the well
- Presence of faulty drainage, allowing ponding within 2m of the well
- Assessing the condition of the drainage if its cracked, broken or needs cleaning
- A faulty or missing fence
- A collection of spilt water in the apron area
- A cracked or damaged apron
- A loose hand pump at the point of attachment
- The condition of the well cover in terms of it being unsanitary
- If the well is open when not in use
- Do people use their own rope and bucket when fetching water
- Are ropes and buckets possibly contaminated when used (e.g. being put on the ground)

3.3.2 WATER SAMPLE COLLECTION

Ten hand-dug wells were randomly selected from the study area, one from each area/zone. The selected areas were: Adebayo, Oke-Ila, Omisanjana, Isato, Poly, Ajilosun, Basiri, Odo-Ado, Aba-Erinfun, and Falegan. The selection criteria for the wells were based primarily on construction pattern and mode of operation of the wells. Other considerations include location in residential areas and accessibility. Water samples at different locations collected for laboratory analysis were taken following standard procedure and immediately labelled on the field using the street names. Rope and bucket system was used in the collection of the water as is normally used by the inhabitants in fetching the water from the hand dug wells. Plastic containers were used for the collection of the water samples. The plastic containers used were pre-treated by washing with 0.05M HCL and was rinsed with distilled water before the collection of samples. The water from the wells was also used to rinse the containers. The sample bottles were tightly covered and kept in ice packed cooler before being transported to the laboratory for chemical analysis. Fast changing parameters such as pH, electric conductivity and temperature were determined insitu. Standard methods were used to determine the parameters such as total dissolved solids, total hardness, calcium hardness, sulphate, alkalinity and chloride. Alkaline-metals such as potassium and sodium were determined using flame absorption spectrophotometer. All reagents used for each samples were prepared and all analysis were done repeatedly.

❖ TEMPERATURE DETERMINATION

The temperature was measured using a mercury thermometer ranging from $0^{o}C$ to $100^{o}C$,

❖ DETERMINATION OF PH

The pH of the samples was electrometrically measured using a well calibrated HANNA Hi208 pH meter.

❖ DETERMINATION ELECTRICAL CONDUCTIVITY

The Electrical Conductivity was measured using DDS-307 Conductivity meter.

❖ DETERMINATION TURBIDITY

Turbidity of the sample was determined after vigorously shaken using Labtech AVI-654 Turbidity meter.

❖ DETERMINATION TOTAL DISSOLVED SOLID (TDS)

The total dissolved solid was measured using HM TDS-3 TDS Meter.

❖ DETERMINATION OF HARDNESS BY TITRATION

Determination of total hardness was achieved through shaking of sample and measuring 25mL into a cylinder which was top to 50mL with distilled water and then poured into a conical flask. 2mL of a buffer solution with a drop of Eriochrome black indicator were added to it. The sample was gently shaken and was titrated with a solution of 0.02EDTA as a titrant to a blue coloration as end point. The actual concentration of total hardness in mg/L as $CaCO_3$ was gotten using the formula given below:

$$\text{Total hardness (mg/L as } CaCO_3) = \frac{A \times B}{Z} \times 1000 \quad (3.2)$$

(Source: APHA, 1985)

Where;

A = mL of titrant used to reach end point

B = 2.5252 and Z = mL of sample used for analysis (25 mL)

❖ DETERMINATION OF CALCIUM BY TITRATION

50ml of water sample was measured into flask. After which 2ml of NaOH and 0.2of murexide was added to the flask. The solution was swirled until the colour turned pink, then the solution was then titrated with EDTA until the colour changed from pink to purple. The readings were taken and recorded. The procedure was repeated for other water samples.

❖ CALCULATIONS FOR CALCIUM HARDNESS, CALCIUM ION, MAGNESSIUM HARDNESS AND MAGNESSIUM ION.

Calcium Hardness mg $CaCO_3$ (CaH) = $\frac{m \times (A \times B) \times 1000}{S}$

Where;

M = molarity,

S = volume of water sample

Calcium ion (Ca^{2+}) = CaH × 0.4

Magnesium ion (Mg^{2+}) = MgH × 0.244

Magnesium Hardness (MgH) = TH – CaH

Total Hardness (TH) = MgH + CaH

Unit mg/l

❖ DETERMINATION OF CHLORINE IN WATER BY ARGENTOMETRIC TITRATION

The sample was well agitated, followed by measuring 100ml into a conical flask. 1mL of standard potassium chromate, K_2CrO_4 (an indicator) was added and the solution was titrated with standard silver nitrate ($AgNO_3$) solution to a reddish-brown colouration as end point. Concentration of chloride in mg per litre of the sample was obtained by applying the formula below;

$$Chloride\ concentration\ (mgL^{-1}) = \frac{A \times N}{Z} \times 35450 \quad (3.4)$$

(Source: APHA, 1985)

Where:

A = mL of titrant used to reach end point

N = Normality of silver nitrate solution = 0.0141

❖ DETERMINATION OF ALKALINITY, CARBONATEAND BICARBONATE IN WATER BY TITRIMETRIC METHOD

Firstly, the burette was run with 0.1M HCl acid stock solution and filled the burette with 0.1HCl acid stock solution to standardize. 50ml of the water sample was measured into a conical flask then 2 drops of phenolphthalein was added to the solution and the colour changed to yellow. It was then titrated against 0.01M HCl acid stock solution until colour changed from yellow to orange. The procedure was repeated for other water samples

Calculating the Alkalinity, Carbonate and Bicarbonate.

The formula below was applied;

$$\text{Carbonate } (CO_3^{2-}) = \frac{carbonate\ titrant\ value\ (ml) \times m \times 1000 \times 60}{S}$$

Where; m = Molarity of the new standardized acid test used, 1000 = conversion to mg/L, 60 = molar mass of carbonate

$$\text{Bicarbonate } (HCO_3^-) = \frac{T.V \times 1000 \times m \times 61}{S}$$

Where; m = molarity of the new standardized acid used, T.V = titre value, 61 = molar mass of HCO_3^-, S = volume of the sample.

ALKALINITY: this is of two types; Phenolphthalein Alkalinity and Total Alkalinity.

Phenolphthalein Alkalinity mg/l $CaCO_3 = \frac{A \times N \times 50,000}{S}$

Where; A = ml standard acid used phenolphthalein endpoint, N = Normality of the new standardized acid used, S = volume of the sample.

Total Alkalinity mg/l $= \frac{A \times N \times 50,000}{S}$

Where; S = volume of the sample, A = Total volume of standardized acid used, N = normality of the new acid.

Unit mg/l

❖ DETERMINATION OF SULPHATE IN WATER

100ml of the water sample was measured into a conical flask and 20ml of standard buffer solution A was added to the solution. A magnetic stirrer was added into the solution and it was placed on the mixing machine. Then 1g of Barium chloride was added into the solution ($BaCl_2$). The solution was stirred for exactly 1 minute at a constant speed. Immediately after stirring, the solution was poured into 10mm cell vial tube and read with U.V Spectrophotometer at a wavelength of 420 nanometre (nm). The procedure was repeated for other water sample.

❖ DETERMINATION OF HEAVY METALS IN WATER SAMPLE

20 ml of the water sample was measured and transferred into 250 ml conical flask. The water sample was digested by the addition of 20 ml of aqua regia (mixture of HCl and HNO_3, ratio 3:1). The beaker was covered with an inverted funnel to prevent excessive loss of sample and heated over a heating mantle at $90^{O}C$ until the volume reduced to about 5ml. The conical flask and funnel were washed with distilled water. The solution was cooled, filtered through Whatman No. 1 filter paper and transferred quantitatively to a 50 mL volumetric flask and made up to the mark with distilled water. The filtrate was transferred into plastic sample bottle and kept. The digested sample was analysed for metals using Buck Scientific 210VGP atomic absorption spectrophotometer (AAS).

❖ DETERMINATION OF SODIUM AND POTASSIUM USING FLAME PHOTOMETER

The beaker was half filled with the water sample. The photometer and the air compressor were switched on. Then the filter selector was set to the required position i.e. either Na or K. The nebulizer inlet tube was inserted in a beaker containing 100ml of distilled water (blank). It was allowed to for 30 minutes for the temperature to stabilize. A set of calibration standard was prepared for sodium and potassium solutions. While aspirating blank, the blank control was adjusted so that the photometer display 0.0 It was allowed for 20 seconds for a stable reading and then adjusted for coarse and fine controls for a convenient reading. The procedure was repeated for different concentration of the standards. The readings of the water samples were then taken. The procedure was repeated for other water sample.

❖ MICROBIOLOGICAL ANALYSIS

The Coliscan® membrane filter method developed for *Escherichia coli* and total coliforms was used.

The sample was filtered through a 47mm, 0.45 m pore size membrane filter. The filter funnel was then rinsed twice with at least 20 ml of sterile diluent to complete the filtration. The filter was then transferred to a petri dish containing a pad saturated with 2 mL of the Coliscan® MF broth, the dish was inverted and the content incubated at about $350^{0}C$ for 24 hours.

The sum of blue/purple and pink/magenta colonies was the total Coliform Positive count. Blue/purple colonies were counted as E. coli. Pink/magenta colonies were counted as other than E. coli coliforms. Clear or white colonies were counted as non-coliforms.

❖ ENUMERATION AND ISOLATION OF TOTAL AND FAECAL COLIFORM COUNT

Total coliforms were estimated using the most probable number (MPN) method. MacConkey's lactose bile salt broth with bromocresol purple as indicator was used for the presumptive tests. With a sterile pipette, 50 ml of each of the water sample was aseptically dispensed into 50ml double strength broth, another 10 ml of the sample into each of the five tubes containing 10 ml double strength broth and another one ml of the sample was then inoculated into each of the second five culture tubes containing 5ml single strength MacConkey broth with Durham's tubes. Inoculated tubes of MacConkey broth were incubated at 37°C for 24 to 48 hours. After 24-48 hours of incubation, the cultures were observed for the presence of acid production and gas formation

A sterile pipette was used to transfer 1ml of the culture from the positive presumptive fermentation tubes into tubes containing 5ml brilliant green lactose bile broth aseptically and incubated for 24-48 hours at 37°C. Following incubation, culture positive tubes were inoculated into MacConkey agar for total Coliform and Eosin Methylene Blue agar for faecal coliform and incubated at 37°C and 44°C respectively.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 SANITARY SURVEY RESULTS

Table 2 presents the qualitative risk profile of the ten areas. This covers all the sampled Hand Dug Wells assessed. All the wells assessed were at risk of contaminations in one way or the other except for a sample from Omisanjana which tends to meet all the criteria for assessing the qualitative risk factors for the hand dug wells, while a well from Basiri is guilty of all the risk factors.

In all, 52% of the wells assessed were moderately at risk of contaminants; 22% of the wells have low and high risks of being contaminated; while wells with very high risk of being contaminated was 4%.

Table 2; Qualitative sanitary risk profile of the assessed Hand Dug Wells in the ten areas

Name	Risk observed	Percent risk score (%)	Qualitative risk score
Falegan I	4,10	20	Low risk
Falegan II	3,4,5,7,9,10	60	High risk
Falegan III	7,10	20	Low risk
Falegan IV	1,2,10	30	Moderate risk
Falegan V	1,2,8,9,10	50	Moderate risk
Falegan VI	1,10	20	Low risk
Falegan VII	10	10	Low risk
Oke-ila I	2,10	20	Low risk
Oke-ila II	7,9,10	30	Moderate risk
Oke-ila III	3,6,7,10	40	Moderate risk
Oke-ila IV	1,2,3,4,5,7,8,9	80	High risk
Oke-ila V	1,5,7,8,10	50	Moderate risk
Oke-ila VI	10	10	Low risk
Oke-ila VII	2,10	20	Low risk

Odo-ado I	7,10	20	Low risk
Odo-ado II	3,6,7,8,9	50	Moderate risk
Odo-ado III	2,3,6,7,8,9,10	70	High risk
Odo-ado IV	4,6,7,8,9,10	60	High risk
Odo-ado V	1,2,6,7,8	50	Moderate risk
Odo-ado VI	1,3,4,5,7	50	Moderate risk
Odo-ado VII	2,3,7,8,10	50	Moderate risk
Adebayo I	7,8,10	30	Moderate risk
Adebayo II	2,7,10	30	Moderate risk
Adebayo III	1,3,4,6,10	50	Moderate risk
Adebayo IV	1,4,5,6,9,10	60	High risk
Adebayo V	1,2,3,9,10	50	Moderate risk
Adebayo VI	1,2,6,9,10	50	Moderate risk
Adebayo VII	1,2,7,9,10	50	Moderate risk
Basiri I	7,10	20	Low risk
Basiri II	2,5,9,10	40	Moderate risk
Basiri III	1,2,3,4,5,7,8,9	80	High risk
Basiri IV	3,4,5,7,8	50	Moderate risk
Basiri V	1,2,3,4,5,6,7,8,9,10	100	Very high risk
Omisanjana I	Nil	0	Low risk
Omisanjana II	5,6,7,8,9,10	60	High risk
Omisanjana III	1,2,7,8,10	50	Moderate risk
Omisanjana IV	3,6,10	30	Moderate risk
Omisanjana V	1,2,3,6,9,10	60	High risk
Ajilosun I	7,8,10	30	Moderate risk
Ajilosun II	5,8,9,10	40	Moderate risk
Ajilosun III	2,3,4,6,7,8,9,10	80	High risk
Ajilosun IV	1,2,3,4,5,6,7,8,10	90	Very high risk
Isato I	4,5,7,8,9,10	60	High risk
Isato II	2,4,5,7,10	50	Moderate risk
Isato III	1,2,5,9,10	50	Moderate risk
Isato IV	1,3,4,5,7,8,10	70	High risk
Poly I	6,7,8,10	40	Moderate risk

Poly II	7,9,10	30	Moderate risk
Poly III	7	10	Low risk
Aba-Erinfun	7,8,10	30	Moderate risk

Key

1 = Is there a latrine/soak-away within 10 m of the well?

2 = Is the nearest latrine on higher ground than the well?

3 = Is there any other source of pollution (e.g. animal excreta, rubbish) within 10 m of the well?

4 = Is the drainage poor, causing stagnant water within 2m of the well?

5 = Is there a faulty drainage channel? Is it broken, permitting ponding?

6 = Is the wall (parapet) around the well inadequate, allowing surface water to enter the well?

7 = Is the concrete floor less than 1m wide around the well?

8 = Are the walls of the well inadequately sealed at any point for 3m below ground?

9 = Are there any cracks in the concrete floor around the well which could permit water to enter the well?

10 = Are the rope and bucket left in such a position that they may become contaminated?

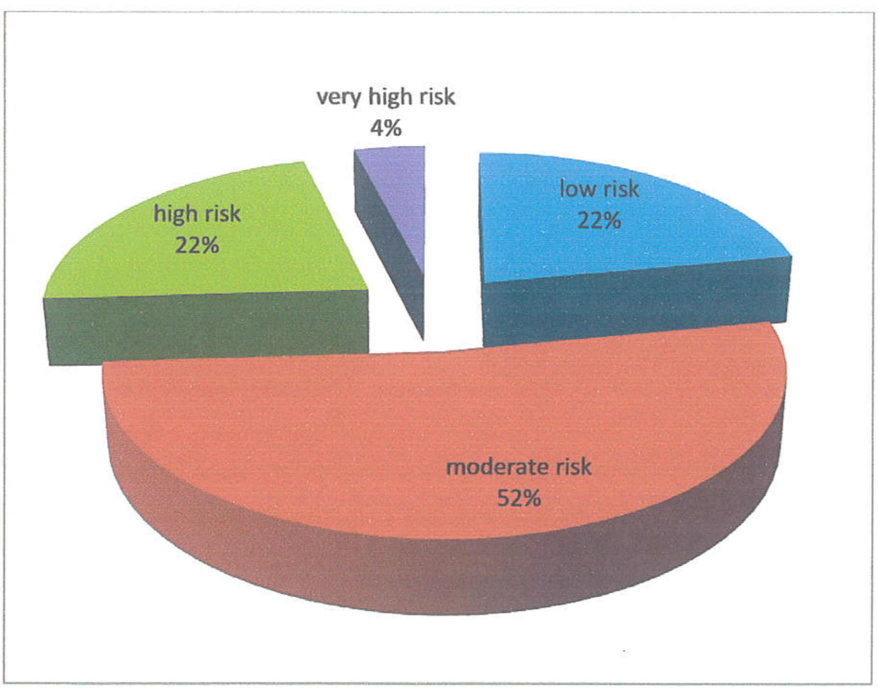

Figure 4: Sanitary risk levels of Hand dug wells

4.2 DISCUSSION

4.2.1 MODE OF OPERATION AND CONSTRUCTION TYPE OF HAND-DUG WELLS

The mode of operation and construction pattern of these wells are presented in Table 3.

The survey revealed that the mode of water abstraction of most of the hand-dug wells was by bucket and rope (88%) while 6% used pump and/or bucket and rope.

Seventy percent (70%) of the wells sampled were semi-protected with the cover being left opened (without lock), the bucket and rope were exposed to contaminants such as dusts, etc; 12% of the wells were unprotected (being without covering such that contaminants could enter); while 18% of the wells sampled were well-protected.

Table 3: Mode of Operation and Type of Construction of the Assessed Hand-Dug Wells

Name	Construction pattern	Mode of operation
Falegan I	Semi-protected	Bucket and rope
Falegan II	Semi-protected	Bucket and rope
Falegan III	Protected	Bucket and rope
Falegan IV	Semi-protected	Bucket and rope
Falegan V	Semi-protected	Bucket and rope
Falegan VI	Protected	Pump/Bucket and rope
Falegan VII	Protected	Bucket and rope
Oke-ila I	Protected	Bucket and rope
Oke-ila II	Semi-protected	Bucket and rope
Oke-ila III	Semi-protected	Bucket and rope
Oke-ila IV	Unprotected	Bucket and rope
Oke-ila V	Semi-protected	Bucket and rope
Oke-ila VI	Protected	Bucket and rope
Oke-ila VII	Semi-protected	Bucket and rope
Odo-ado I	Protected	Pump
Odo-ado II	Semi-protected	Bucket and rope
Odo-ado III	Semi-protected	Bucket and rope
Odo-ado IV	Semi-protected	Bucket and rope
Odo-ado V	Semi-protected	Bucket and rope
Odo-ado VI	Semi-protected	Bucket and rope

Odo-ado VII	Semi-protected	Bucket and rope
Adebayo I	Semi-protected	Bucket and rope
Adebayo II	Semi-protected	Bucket and rope
Adebayo III	Semi-protected	Bucket and rope
Adebayo IV	Semi-protected	Bucket and rope
Adebayo V	Semi-protected	Bucket and rope
Adebayo VI	Semi-protected	Bucket and rope
Adebayo VII	Semi-protected	Bucket and rope
Basiri I	Protected	Pump
Basiri II	Semi-protected	Pump/bucket and rope
Basiri III	Semi-protected	Bucket and rope
Basiri IV	Semi-protected	Bucket and rope
Basiri V	Unprotected	Bucket and rope
Omisanjana I	Protected	Pump
Omisanjana II	Semi-protected	Bucket and rope
Omisanjana III	Semi-protected	Bucket and rope
Omisanjana IV	Semi-protected	Bucket and rope
Omisanjana V	Semi-protected	Bucket and rope
Ajilosun I	Semi-protected	Bucket and rope
Ajilosun II	Unprotected	Bucket and rope
Ajilosun III	Unprotected	Bucket and rope
Ajilosun IV	Unprotected	Bucket and rope
Isato I	Semi-protected	Bucket and rope
Isato II	Semi-protected	Bucket and rope
Isato III	Semi-protected	Pump/Bucket and rope
Isato IV	Semi-protected	Bucket and rope
Poly I	Semi-protected	Bucket and rope
Poly II	Semi-protected	Bucket and rope
Poly III	Protected	Bucket and rope
Aba-Erinfun	Unprotected	Bucket and rope

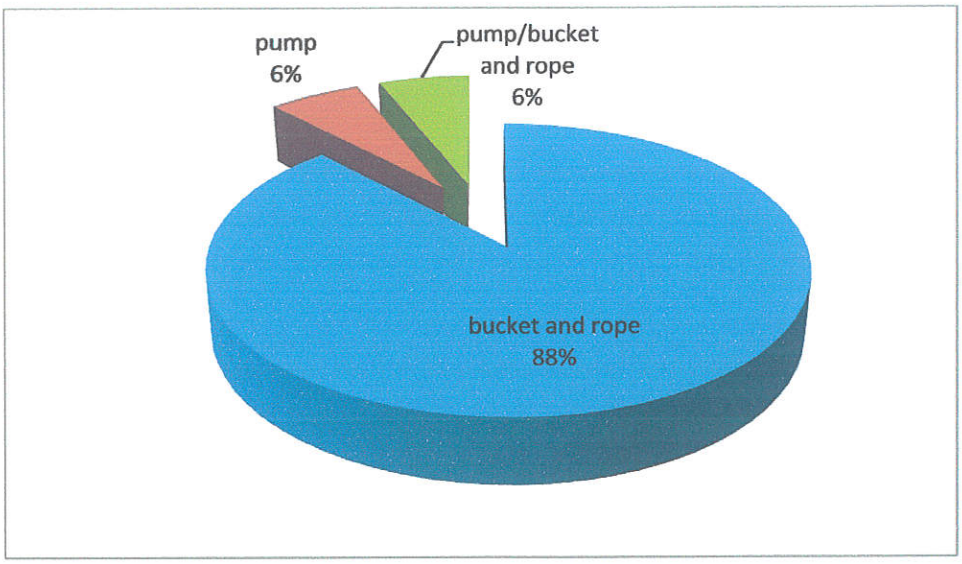

Figure 5: Mode of operation of sampled hand-dug wells

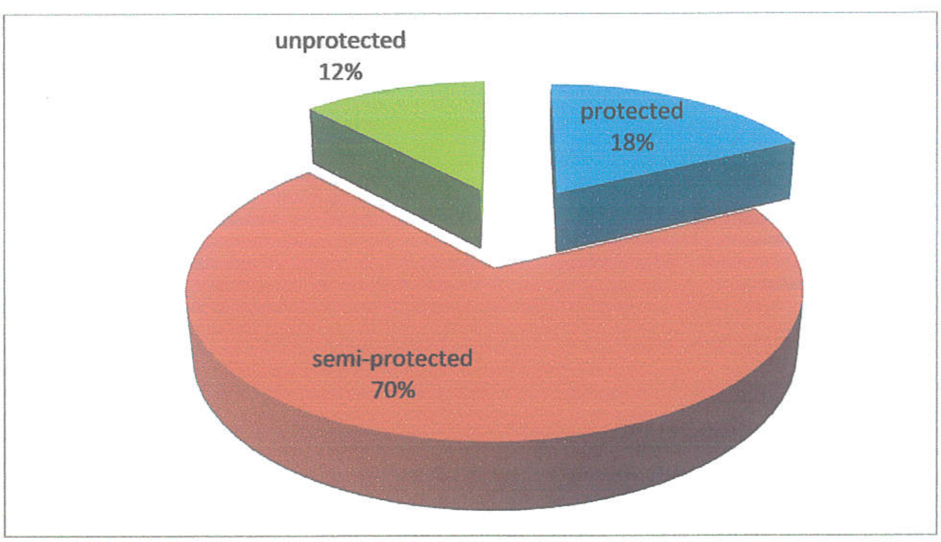

Figure 6: Construction patterns of hand-dug wells

4.2.2 ASSESSMENT IN RELATION TO SANITARY CONDITIONS

Table 4 showed that the common risk identified during the cause of the survey includes: cracked and inadequate apron (less than 1m) around the wells; lack of adequately sealed well lining up to 3m below the ground level; presence of uphill latrine/ soak away and; the exposure of the fetching rope to dusts and being placed on the ground and the fetching containers improperly placed.

Table 4: Wells Assessment in Relation to Sanitary Conditions

Sanitary risk factor	Number of wells	Percentage (%)
Latrine/soak-away within 10m of the well	19	38
Presence of an uphill latrine	21	42
Source of pollution within 10m of well	17	34
Poor drainage causing stagnancy of water within 2m of well	14	28
Presence of faulty or broken drainage channel	16	32
Lack of adequate headwall	15	30
Lack of adequate apron around well head	32	64
Lack of adequate seal up to 3m below ground level in the well	22	44
Cracked concrete apron permitting inlet of surface water into the well	21	42
Possible contamination from abstraction method	42	84

It was also noted that the wells with very high risk score are unprotected and use bucket & rope method of abstracting water. The sampled wells with the low and risk scores all have pumps installed as a mean of abstraction, hence the low risk associated with these wells.

From the results presented in Table 4, it was seen that 84 % of the sampled wells stand a risk of possible contamination from the method used to abstract the water from these wells and have less adequate apron around the well head while 64% of the sampled wells lacked adequate apron. It was also seen from the results that 44% of these sampled wells do not possess adequate well seal. 42% of the wells sampled are located downhill of either a latrine or a soak away while same percentage was found for wells with cracked concrete apron which could permit inlet of surface water into the well. Meanwhile, less than 40% of the sampled wells had the risk of been contaminated with latrine/soak-away within 10m of the well (38%), pollution within 10m of well (34%), presence of faulty or broken drainage channel (32%), lack of adequate headwall (30%) and poor drainage capable of causing stagnancy of water within 2m of well.

The results of the physiochemical and the microbial analysis of the water samples are given in APPENDIX 2

4.2.3 MICROBIAL QUALITY OF THE WATER SAMPLES

Table 5: Comparing the Microbial Parameter of Water Samples from the Hand Dug Wells with the WHO and NSDWQ standards

	total coliform count (cfu/100ml)	Faecal streptococci (cfu/100ml)	E. coli (cfu/100ml)
WHO	0	Negative	Negative
NSDWQ	10	Negative	Negative
Adebayo	0.84×10^2	positive	Positive
Poly	0.26×10^2	Negative	Negative
Isato	0.71×10^2	Positive	Positive
Ajilosun	0.40×10^2	Negative	Positive
Basiri	0.41×10^2	Negative	Positive
Odo-Ado	0.76×10^2	Positive	Positive
Aba-Erinfun	0.97×10^2	Positive	Positive
Oke-ila	0.76×10^2	Positive	Positive
Omisanjana	0.56×10^2	Positive	Positive
Falegan	0.57×10^2	Positive	Positive

The quantitative aspect of microbial analysis was compared with the WHO and NSDWQ presented in Table 5 above indicated that all the 10 samples were heavily contaminated with Total coliform count. The total coliform count for the hand dug wells varied from 0.26×10^2 to 0.97×10^2 coliforms per 100ml and when compared with the acceptable standards prescribed by both WHO and NSDWQ (0 and 10 coliforms per 100 ml respectively). The lowest Total Coliform Count of 0.26×10^2 coliforms per 100 ml was recorded for the water sample taken at poly and the highest value for the total coliform count of 0.97×10^2 cfu/100 ml was recorded at Aba-Erinfun wells.

The samples were generally contaminated with faecal streptococci except for the sample from polytechnic environment; Ajilosun and Basiri. Also all the samples tested positive for E. coli except for samples from polytechnic environment.

According to WHO (2006), effect of the intake of water contaminated with E. Coli include: Urinary tract infections, bacteraemia, meningitis, diarrhoea, (one of the main cause of morbidity and mortality among children), acute renal failure and haemolytic anaemia.

4.2.4 CHARACTERISTICS OF THE SAMPLED WELL WATER

The results of the elemental characteristics and physiochemical parameters of the sampled wells compared with the WHO and NSDWQ standards are presented in Table 6 and 7. The samples were colourless and odourless except for sample obtained from Aba-Efinrun that appeared slightly milky.

Table 6: ELEMENTAL CHARACTERISTICS OF THE SAMPLED HAND DUG WELLS

	Fe^{2+} (mg/l)	F^- (mg/l)	Cl^- (mg/l)	Na^+ (mg/l)	Ca^{2+} (mg/l)	K^+ (mg/l)	Mg^{2+} (mg/l)	Mn (mg/l)
Adebayo	1.3	1.0	8.7	177	215	321	22.775	0.720
Poly	0.2	0.1	7.1	98	167	250	19.325	0.622
Isato	2.5	1.0	16.0	203	320	412	42.600	0.523
Ajilosun	1.7	1.0	10.7	214	335	295	28.750	0.813
Basiri	0.8	1.4	8.5	153	212	308	19.325	0.558
Odo-Ado	0.4	1.0	9.0	233	332	416	30.625	0.673
Aba-Erinfun	1.0	1.4	17.8	167	265	433	51.575	0.842
Oke-ila	0.8	1.2	7.8	184	302	258	27.350	0.533
Omisanjana	0.5	0.2	7.1	83	197	237	13.325	0.479
Falegan	0.4	0.1	9.9	128	263	224	15.125	0.590
NSDWQ	0.3	1.5	250	-	-	-	-	-
WHO	0.3	1.5	250	-	75	-	-	-

WHO: World Health Organization, (2011).

NSDWQ: Nigeria Standard for Drinking Water Quality, (2010).

Table 7: physiochemical characteristics of the sampled hand dug wells

	Turbidity (NTU)	PH	TDS (mg/l)	Conductivity (µS/cm)	Alkalinity (mg/l)	Hardness (mg/l)	SO_4^{-2} (mg/l)	NO^{-3} (mg/l)
Adebayo	1.0	4.9	243	387	208	10.70	98.2	14.8
Poly	1.0	5.7	64	103	127	6.87	40.0	11.7
Isato	4.0	6.3	481	758	440	13.70	81.4	17.9
Ajilosun	1.0	4.9	194	305	185	7.80	77.4	15.6
Basiri	1.0	5.8	133	205	136	9.27	50.0	11.7
Odo-Ado	2.0	6.1	338	531	276	12.80	81.4	14.8
Aba-Erinfun	3.0	5.8	345	531	300	11.60	87.3	17.9
Oke-ila	1.0	6.0	256	401	274	7.41	78.2	12.4
Omisanjana	1.0	5.1	64	100	214	7.47	42.3	9.0
Falegan	1.0	5.7	95	137	191	7.01	63.7	9.0
NSDWQ	5.0	6.5-8.5	500	1000	150	500	100	50
WHO	5-25	6.5-9.2	500-1000	-	150	500	100	50

WHO: World Health Organization, (2011).

NSDWQ: Nigeria Standard for Drinking Water Quality, (2010).

Sulphates: Adebayo wells has the highest amount of sulphate (98.2 mg/L) and close to that was found of Aba-Erinfun with 87.3mg/L, while the lowest was gotten from poly with 40.0mg/L and closest to that was Omisanjana with 42.3mg/L. Isato and Odo-Ado have 81.4mg/L each. The values obtained for each of the ten locations in this study were lower when compared with both the WHO and NSDWQ permissible limits. This agreed with the findings of Talabi (2016), in the study area. The sulphate concentration in the water samples is incapable of causing offensive odour. Higher level of sulphate in any water source is an indicative of some form of pollution; and can have adverse effect on human health; causing diarrhoea (DWAF, 2001).

Nitrates: Nitrate concentration ranged from 9 mg/l to 17.9 mg/l with a mean and standard deviation value of 13.48 and 3.24respectively. The result showed that nitrate concentration was below the NSDWQ and WHO permissible limit of 50 mg/L. This implies that the well waters have a low level of oxidized organic matter. This is however contrary to the research carried out by Talabi (2016) that showed that the concentration of nitrate in the well water of the study area was above 50 mg/l.

Chlorides: The concentration of chlorides ranged from 7.1 mg/l to 17.8 mg/l with an average concentration of 10.26 mg/l and standard deviation of 3.70 mg/l. This concentration was found to be lower compared to the highest permissible limit set by the Nigeria Standard for Drinking Water Quality and the World Health Organization. Although no health-based guideline value is proposed by NSDWQ and WHO for chloride in drinking-water, however, chloride concentrations in excess of about 250 mg/l can give rise to detectable taste in water and excessive intake of drinking-water containing sodium chloride at concentrations above 250 mg/l has been reported to produce hypertension (Fadeeva, 1971), this effect is believed to be related to the sodium ion concentration. Chloride also increases the electrical conductivity of water and thus increases its corrosivity. In metal pipes, chloride reacts with metal ions to form soluble salts, thus increasing levels of metals in drinking-water (EURO Reports, 1979).

Total Dissolved Solid: The values were lower than the recommended value of 500 mg/L by the National guideline and standards for water quality in Nigeria and the WHO specification limits (1000 mg/L) for drinking water. Isato had the highest amount of TDS (481 mg/l) and the lowest (64 mg/L) for Poly and Omisanjana wells. The presence of high levels of TDS in drinking-water may be objectionable to consumers WHO (2011).

Alkalinity: This ranged from 127 mg/l in the sample from Poly to 440 mg/l in the water sample from Isato, with average alkalinity of 235.1mg/l. The values of this parameter for the wells were higher when compared to the permissible limits of WHO and NSDWQ (150 mg/l respectively). This may be due to the presence of carbonates and bicarbonates in the well water because they contribute to the hardness of the water (Magit, 2002). Higher concentration of alkalinity in the water samples can lead to corrosion of metals.

Hardness: Isato has the highest hardness (13.7 mg/L) close to this were Odo-Ado and Aba-Erinfun with 12.8 mg/L and 11.6 mg/L respectively. The lowest was recorded for Poly with 6.87mg/l. According to the WHO's guideline for drinking water quality, (2011), water with hardness less than 100 mg/l is classified as soft water and this have a low buffering capacity and is more corrosive for water pipes.

Turbidity: The turbidity recorded for the samples was in conformity with the permissible limits that are recommended by WHO and NSDWQ of 5NTU. Highest amount was recorded for Isato and Aba-Erinfun with 4.0NTU and 3.0NTU respectively others have 1.0NTU except for Odo-Ado with 2.0NTU. The high content of iron in the water sample from Isato could be responsible for the high turbidity level in the water. It was given that the greater the turbidity, the higher the risk of gastro-intestinal diseases (Eric & Catherine, 1997).

Iron: The concentration of iron in the water samples ranged from 0.2 mg/l to 2.5 mg/l with a mean of 0.96 mg/l. Only the water sample from Poly was within the limit set by the WHO and NSDWQ (0.3mg/l), the highest Fe^{2+} was recorded for Isato with 2.5mg/L while the lowest was recorded for poly with 0.2mg/l. There is usually no noticeable taste at iron concentrations below 0.3 mg/l, although turbidity and colour may develop (WHO, 2011).

Fluoride: The lowest concentration of fluoride was recorded for both samples from Poly and Falegan with 0.1 mg/l and close to these was found in the water sample from Omisanjana with 0.2 mg/l, the highest was however recorded for Basiri and Aba-Erinfun. All the water samples are within the permissible limits given by both the WHO and NSDWQ (1.5 mg/l). Fluoride, although known to prevent early stage tooth decay, concentrations above 1.5 mg/l carry an increasing risk of dental and skeletal fluorosis. High level of its concentration in drinking water and food have been found to have serious health effects in humans and animals, like mottled teeth that occur in children (Mcdongh et al., 2004).

Sodium: The concentrations of sodium ranged from 83 mg/l to 233 mg/l with a mean value of 164 mg/l. While the least concentration was obtained from Omisanjana, the highest value was noted in Odo-Ado. The mean value was above the WHO recommended intake. There was no limit proposed by the WHO and NSDWQ, however, sodium may affect the taste of drinking-water at levels above about 200 mg/l (WHO, 2003) and also according to USEPA (2003), high concentration of sodium in drinking water is a health concern which may cause hypertension (high blood pressure) for individuals.

Calcium: The mean concentration was 260.80mg/l, highest concentration was gotten from water sample from Odo-Ado with 233 mg/L. Ajilosun and Isato were closer with calcium ion concentration of 214 mg/l and 203 mg/l respectively. The lowest was found in samples from Omisanjana and Poly with 83mg/L and 98mg/l. The amount of calcium found in the water samples did not conform to the permissible limit set by the WHO (75 mg/l). Calcium intrusion into the ground water may result from the leaching of soil and other natural sources or may come from manmade sources such as sewage and some industrial wastes. Calcium is usually one of the most important contributors to hardness.

PH: The pH content of the water samples in the study area ranges from 4.9 in samples from Adebayo and Ajilosun to 6.3 in Isato with mean value of 5.6. The water samples from the study area were slightly acidic in nature suggesting that the activity of hydrogen ions in the water samples in the area were more than that of the hydroxyl ions. This low pH may be due to the release of chemical gasses, e.g. sulphur-dioxide, nitrogen dioxide, carbon monoxide, from bush burning, combustion (organic and inorganic), and vehicular emissions that generate acidic rains and water, which infiltrate into the ground and lowers the pH of the water. Besides, decaying vegetation could also produce some amount of tannic (weak) acids (Adeyemi, O., Oloyede, O.B. and Oladiji, A.T., 2007). Typically, the obtained pH values in this study fall below the World Health Organization and the Nigeria Standard for Drinking Water Quality of 6.5-8.5 and 6.5-9.2 respective standards. When pH values is less than 6.5, it causes corrosion and the subsequent release of metals such as zinc, copper, and lead from pipes and plumbing fixtures into the water, these substances can be toxic to humans (WHO,20110).

Potassium: From the collected samples, potassium ions were found to be of high concentrations in Ajilosun, Odo-Ado, Isato and Oke-Ila water sampleshaving 335 mg/l, 332 mg/l, 320 mg/l and 302 mg/l values respectively. The lowest was found in the sample from poly (167 mg/l) and closest to this is 197 mg/l from the sample from Omisanjana. Though the World Health Organization and the Nigeria Standard for Drinking Water Quality did not set a permissible limit for potassium concentration in drinking water, it was however stated that high amount of potassium can cause stomach upset, nausea, diarrhea, vomiting, intestinal gas, and other side effects. Too much potassium is unsafe and can cause feelings of burning or tingling, generalized weakness, paralysis, listlessness, dizziness, mental confusion, low blood pressure, irregular heart rhythm, and death (Adrogue HJ & Madias NE, 2014).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The study showed that almost all of the hand-dug wells were at risk; identified sources of pollution with lack of adequate apron around well head, possible contamination from abstraction method, cracked and inadequate apron (less than 1m) around the wells; lack of adequately sealed well lining up to 3m below the ground level; presence of uphill latrine/ soak away and; the exposure of the fetching rope to dusts and being placed on the ground and the fetching containers improperly placed.

For the physiochemical parameters of the water samples from the wells; Calcium, pH, Alkalinity, Manganese and Iron contents were above the permissible limits as recommended by WHO and NSDWQ set limits. Only water sample from Poly environment is in conformity with the given standards for Iron concentration. The results also showed that all the samples of the waters from the hand-dug wells were positive to total coliform count (100%), faecal streptococci (70%) and e. coli (90% of water samples) which rendered the well water unsuitable for human consumption.

5.2 RECOMMENDATION

Based on the findings of the study and from personal observation, the following recommendations are made to help improve the quality of well water in the study area.

- It is essential that knowledge about the method of sanitary risk assessment of hand-dug wells and other groundwater sources be disseminated and made known to the public. In this regard, the establishment of National On-site Sanitation Study Bureau would be a great development. Awareness programmes to enlighten the public should also be carried out on a regular basis.
- The sanitation team and agencies should educate owners of private hand-dug wells to keep the head of their wells clean and routinely disinfect the well.
- Residents should be encouraged to construct wells with concrete linings, sited at least 10m away from latrines according to WHO standards and sited at higher elevation to prevent well contamination.
- Stakeholder participation aside the Municipal Assembly should be encouraged to invest more in the water sector through the provision of safe water, disinfectants, investment in researches and in the education of inhabitants on sanitation and water management practices.
- The implementation of regulations on safe drinking water by the Standard Organization of Nigeria (SON) and other enforcements agencies will go a long way to reduce incidences of water pollution and associated water borne diseases.

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APPENDIX 1

Sanitary Assessment Form of Hand-Dug Well

A. General Information

Ward ....

Water Sample Code no ....

Date of Visit ....

B. Identification of Sanitary-risk factors

	Yes	*No*
1. Is there a latrine within 10m of the well?	☐	☐
2. Is the nearest latrine on the higher ground than the well?	☐	☐
3. Is there any other source of pollution (e.g animal excreta, rubbish) within 10m of the well?	☐	☐
4. Is there poor drainage, causing stagnant water within 2m of the well?	☐	☐
5. Is there a faulty drainage channel? Is it broken, allowing ponding?	☐	☐
6. Is the headwall (parapet) around the well inadequate, allowing surface water to enter the well?	☐	☐
7. Is the concrete floor less than 1m wide around the well?	☐	☐
8. Are there walls of the well (well-lining) inadequately sealed?	☐	☐
9. Are there any cracks in the concrete floor around the well which could permit water to enter the well?	☐	☐
10. Are the rope bucket exposed to contamination?	☐	☐

Total Score of risks………/10

Sanitary risk score: 9, 10 -Very high
6, 7, 8 - High
3, 4, 5 - Moderate
0, 1, 2 – Low

Signature of Sanitarian..

APPENDIX 2

Results of the physiochemical parameters

AFE BABALOLA UNIVERSITY ADO-EKITI (ABUAD)

COLLEGE OF SCIENCES, RESEARCH & EXTENSION UNIT

DATE RECEIVED : 27/04/17
SAMPLE BROUGTH IN BY : MR TOPE
SAMPLE REF NO :RE/17/31002
METHOD OF ANALYSIS : SPECTROMETRY
INSTRUMENT USED :AAS BUCK SCIENTIFIC 210VGP & FLAME PHOTOMETER FP 902

SAMPLE CODES	Na (ppm)	Ca (ppm)	K (ppm)	Mg (ppm)	Mn (ppm)
A	177.000	215.000	321.000	22.775	0.720
B	98.100	167.000	250.000	19.325	0.62[illegible]
C	202.800	320.000	412.000	42.600	0.523
D	214.000	335.000	295.000	28.750	0.813
E	153.000	212.000	308.000	19.325	0.553
F	232.600	332.500	416.000	30.625	0.673
G	166.500	265.000	433.000	51.575	0.842
H	184.000	302.000	258.000	27.350	0.533
I	82.800	197.000	237.000	13.325	0.479
J	128.000	262.500	224.000	15.125	0.590

08-05-17

ANALYST'SIGNATURE &DATE