QUALITY OF WATER FROM PROTECTED SPRINGS AND HOUSEHOLD STORAGE CONTAINERS IN FOUR LOCAL GOVERNMENT AREAS IN IBADAN, NIGERIA.

BY

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CERTIFICATION

I certify that this research work was carried out by Amaka Tonia NZOM in the Department of Environmental Health Sciences, Faculty of Public Health, College of Medicine, University of Ibadan, Oyo State.

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DEDICATION

I dedicate this work to THE BLESSED VIRGIN MARY, my Queen and Mother and THE DIVINE MERCY OF JESUS.

ACKNOWLEDGEMENT

Finally, I have come to a point I have longed for, the end of a long journey. My deepest and unwavering gratitude I give you Lord, only you know the depth of my thanksgiving. I thank you.

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ABSTRACT

Springs produce water which is considered to be wholesome. Spring water potability in Ibadan, compromised by contamination at source and consumers' unhygienic household practices has not been well investigated. This study therefore assessed water quality from protected springs and household practices that may affect spring water quality in Ibadan.

This cross-sectional study involved purposive selection of seven out of the 26 protected springs located in Ibadan North, Ibadan North East, Egbeda and Ona-ara Local Government Areas. A validated semi-structured questionnaire was used to interview men and women involved in water collection from 400 randomly selected households. Standardized sanitary inspection forms consisting of thirteen points for springs and household storage containers were used to collect data on the risk of contamination. Duplicate water samples were collected from springs during dry and rainy seasons for physico-chemical and bacteriological analysis, while forty spring water samples stored in household containers were also collected for bacteriological analysis using standard method adopted by the American Public Health Association. Data were analysed using descriptive, t-test and Spearman correlation statistics.

The participants' mean age was 38±14.0 years and 83.4% were women. Of those who treated their water, 12% boiled the water, 9% filtered and 20% added alum before use. Thirty-three percent washed their storage containers daily, 65% of storage containers were insanitary and liable to rust, crack or leak, 55% of households had dirty ladles, and 70% of households drink from the ladle for drawing water from the containers, while animals had access to the storage containers in 17.5% of households. Faecal matter was found uphill in four springs, mechanic workshop was located beside two springs, and pool of stagnant water was found within the vicinity of three springs. Positive correlation (0.441) exists between mean sanitary risk score (8±1.9) and *E.coli* count (1000cfu/ml), during the rainy season, implying gross pollution of the springs and high risk to consumers. The mean physico-chemical parameters of the springs during dry and rainy seasons respectively were within the WHO limits viz: total hardness (59.4±10.7 and

50.6±8.6)mg/l, lead (0.01±0.0 and 0.01±0.0)mg/l and nitrate (8.1±2.2 and 8.5±1.6)mg/l. For three springs, electrical conductivity (777±1.4; 437.5±4.9; 789±11.3)µS/cm showed results higher than WHO/European commission limit of 400µS/cm during the rainy season. Total coliform count of the springs which greatly differed during dry (4600cfu/ml) and rainy (2250cfu/ml) seasons was significantly higher than WHO limit of 10cfu/ml. During dry season, five springs (500,1000,700,600&350cfu/100ml) had *E.coli* count greater than WHO recommended limit of 0cfu/100ml. Similarly, all seven springs during rainy season had *E.coli* count (20,25,20,1000,1800,1800&1800cfu/100ml) greater than WHO limit. *E.coli* count reduced significantly from source (1000cfu/100ml) to households (14cfu/100ml).

There was pollution at the springs as shown by the high bacterial load, consequently, exposing consumers to the risk of water-borne diseases. This could be controlled by frequent chlorination, improvement of sanitary conditions and education on handling practices. Use of different water treatment schemes like solar disinfection is advocated, as well as regular cleaning and disinfection of storage containers.

Keywords: Protected springs, water quality, sanitary inspection, sanitary risk score.

Word count: 488

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CHAPTER ONE

INTRODUCTION

1.1 Background

Water is essential for life and a basic requirement for the healthy functioning of all the world's ecosystems (Lenton*et al.*, 2005). It exists in three forms- gas, liquid and solid- depending on the prevailing temperature. In its purest form, water exhibits physical properties of 100^oC for its boiling point, 0^oC for its freezing and has a density of 1. All chemical substances that exist in dual state, solid or liquid, contract as they grow cooler. However, water has quite a distinct characteristic. With a fall in temperature, it contracts, but a further decrease below +4 ^oC, water begins to expand which leads in an increase in volume. In its solid state, water differs from other substances, in that it floats on the surface instead of sinking. This is explained by its further expansion as it freezes.

The chemical properties of water are such that they allow life to perpetuate. Plants carry water from the depths of the soil up to the top of large trees (UNEP and WHO, 1996). If the surface tension of water were low, as in the case of many other liquids, the plants could not absorb water. This would be the end of vegetation and animal kingdom.

Adequate hydration is an absolute requirement for health and all active life. This need is felt in the great value placed on this peculiar substance. Water constitutes more than half of the human body, varying between individuals and generally dropping with a corresponding increase in age (Walters, 2008).

The amount of freshwater on earth is limited, and its quality is under constant pressure. A higher percentage of about 97% of all waters on earth is contained in the ocean, while the remaining 3% sustains life on earth (USGS, 2010). Hence, preserving the quality of freshwater is important for drinking water supply, food production and recreational water use.

1.1.1 Role of Water in Socio-Economic Development and Civilization

Human development and population growth exert many and diverse pressures on the quality and quantity of water resources and on access to them. Access to potable drinking water was and still is a major factor in socio-economic development and civilization. Historically, civilization has flourished around major water ways: the inhabitants of the ancient city of Egypt depended solely on the Nile River. Trade flourished around cities that have easy access to water bodies. Large metropolises such as London, Paris, Tokyo, New York city and Lagos owe their success in part to their proximity and the resultant expansion of trade via water.

Water is critical to all facets of sustainable development from environmental protection and food security to increased tourism and investment; from women empowerment and education of girl-child to reductions in productivity losses due to illness and malnutrition (Lenton*et al.*, 2005). Thus, increasing access to domestic and potable water supply as well as improving water resources management is an entry point for efforts to help in the development of countries.

1.1.2 Water and Development

Access to safe, potable and adequate water is critical to the development of any nation**.** The growth and development of any nation to a large extent depends on the quality and quantity of water available to its citizenry. A necessary condition for sustainable development is the availability of water in adequate quantity and quality (Kundzewicz, 1997).

The Millennium Development Goal (MDG) on water and sanitation, Goal 7: Target 10 states that by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation will be halved (UN, 2013). The attainment of the MDG will not only provide good health, but will have a positive impact on the economy of all nations.

The recommendation for MDG on water and sanitation: The international community needs to support African countries in implementing national strategies to achieve the water supply and sanitation targets. This will require an estimated US$5.8 billion per year in external financing (UN, 2008a).

In a recent report from UN (2013), over the past 21 years, more than 2.1 billion people gained access to improved drinking water sources; with 89% of the global population having access to improved sources of drinking water in 2010. This means that the MDG drinking water target was met 5 years ahead of schedule, despite significant population growth.

1.1.3 Impact of Water on Public Health

The adverse impact on public health from poor water supply have long been recognised in both developing and developed countries, taking the form of disease outbreaks and also contributing to disease load of any community (Ford 1999; Payment and Hunter 2001). Water-related infectious diseases of public health importance, such as cholera, have influenced social and political development. Since 1817, there have been at least seven (7) cholera pandemics and most have provided examples of issues of pathogen emergence (WHO, 2003).

One of the causes of child mortality is as a result of lack and unsafe drinking water. Nearly 2 in 10 children have no source of safe drinking water. This proportion has led to a daily child mortality of 3,900, especially in Africa and Asia (Lenton*et al.*, 2005).

According to WHO (2003), about 80% of all diseases and one third of all deaths in developing countries are related to water-related diseases, such as diarrhoea, malaria, schistosomiasis, river blindness, guinea worm, and others which kill globally perhaps 25,000 human beings a day.

The magnitude of the public health gains derivable from use of safe, improved and increased volumes of water are felt directly in all aspects of health, social life and economy of a nation. Most importantly, improved access to clean and potable water supply, a major public health benefit, is achieved. There is also an increase in time saved from the lengthy distance travelled to collect water and time involved in water collection. The time saved could be channeled to productive activity (including education), child care, small-scale business and food preparation. The health gains accruing from improved and increased volume of water are felt in the control and reduction of water-borne diseases, especially diseases transmitted by the faecal-oral route. In places where basic access service level of clean and potable water has not been achieved, hygiene cannot be assured and consumption of water may be a risk (Howard and Bartram, 2003).

1.1.4 Global Water Consumption and Access.

Globally, one billion people are currently without access to improved water supply. Most of these people live in Asia and Africa. For example, in Africa, 2 out of 5 people lack improved water supply (WHO and UNICEF, 2008). According to Shiklomanov (2000), as at the year 2000, 27% of the population of lesser developed countries did not have access to safe drinking water.

Figure 4.1 shows the global water stress with the indicators. Some of the indicators highlighted are droughts, extended dry seasons and shrinking glaciers.

As reported by Lenton*et al,* (2005), the countries where access to water is poor and progress toward the Millennium Development Goal is stalled or reversing include five in Africa (Ethiopia, Mauritania, Madagascar, Guinea, and Togo), one in East Asia and the Pacific (Papua New Guinea), two in the Arab States (Oman and Libyan Arab Jamahiriya), and one in Latin America and the Caribbean (Haiti). Countries with better prospects for meeting the goal but where challenges are still formidable include eight in Africa (Uganda, Malawi, Cameroon, Niger, Nigeria, Namibia, Côte d'Ivoire, and South Africa), two in East Asia and the Pacific (China and the Philippines), and one in Latin America and the Caribbean (Trinidad and Tobago).

Access to drinking water is measured by the Millennium Development Goal (MDG) indicator of proportion of population using improved drinking water source (WHO/UNICEF, 2012). In Sub-Saharan Africa, a total of 63% of the population were shown to have access to an improved source of drinking water in 2011 as against in 1990. (Table 1.1)

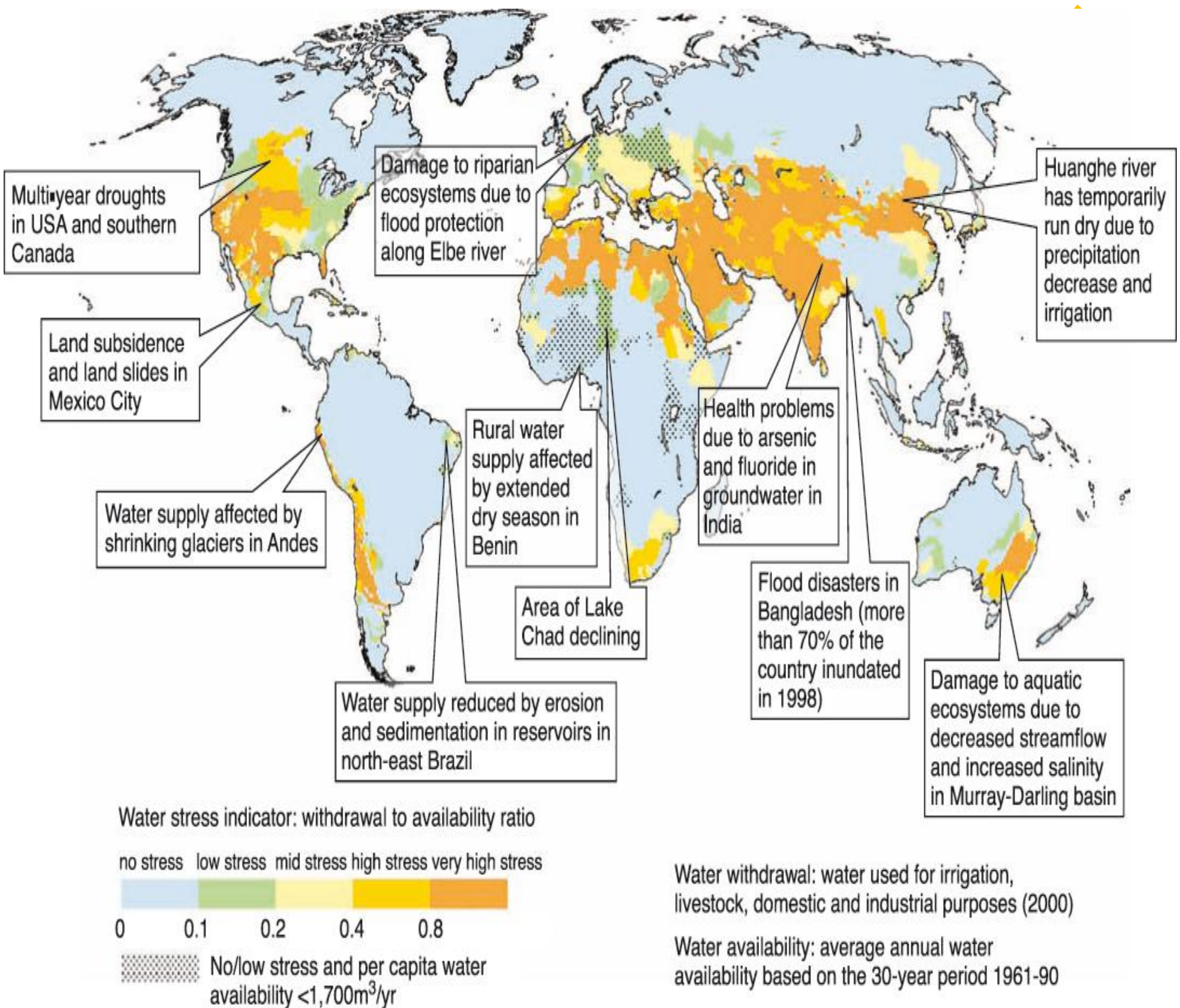


Figure 1.1: Global Water Stress Map.

Source: Chung (2008)

Table 1.1: Proportion of Population Using Improved Source of Drinking Water (%)

	1990			2011		
	Total	**Urban**	**Rural**	**Total**	**Urban**	**Rural**
World	76	95	62	89	96	81
Developing Regions	70	93	59	87	95	79
Northern Africa	87	94	80	92	95	89
Sub-Saharan Africa	49	83	36	63	84	51
Latin America and the Caribbean	85	94	64	94	97	82
Eastern Asia	68	97	56	92	98	85
Eastern Asia excluding China	96	97	93	98	100	91
Southern Asia	72	90	66	90	95	88
Southern Asia excluding India	78	94	72	87	93	84
South-Eastern Asia	71	90	62	89	94	84
Western Asia	85	95	69	90	96	78
Oceania	50	92	37	56	95	45
Caucasus and Central Asia	89	97	81	86	96	79
Developed Regions	98	99	94	99	100	97

Source: UN, 2013.

1.1.5 Water Supply Situation in Ibadan

In her efforts to adequately manage challenges posed by environmental factors, the Oyo State Government of Nigeria in 1992, requested to join other 14 cities across the world already engaged in the SCP/EPM process. By 1994, the Sustainable Ibadan Project (SIP) came into reality by the endorsement of the UN-Habitat. Consequently, many environmental problems were identified, prioritized and solutions were sought. These included: street trading, mismanagement of water shed, urban poverty, housing shortages, poor accessibility and unplanned city growth, shortages in water supply, gross inadequate public utilities and poorly managed solid waste disposal. Of these, waste and water management were topmost on the list and required urgent and immediate attention. To this effect, working groups for water and waste management were formed (SIP, 2004).

Some of the working groups were involved in water management- natural spring water development, boreholes and deep well, as well as, mini water schemes.

The spring water development project started in 1996 with the rehabilitation and protection of three (3) natural springs: Akeu/Osun in Ibadan North-East LGA, Moga in Ona-ara LGA and Agbadagbudu in Ibadan North LGA. These were completed in November 1996, April 2002 and May 2002 respectively. Subsequently, replicates of these protected springs were developed- Onipasan, Sango/Isopako and Adegbayi in Ibadan North East, Ibadan North and Egbeda LGAs respectively. Later, the Yemoja-Olodo natural spring was rehabilitated (SIP, 2004)

1.2 Problem Statement

Water is essential for both economic and social welfare of a nation. A nation is not regarded as developed without the provision of safe, clean and potable water for its citizenry. The quantity and quality of water delivered or obtained and used by households is pertinent for domestic water supplies. It influences sanitation, hygiene and the health of the public in general. The quantity of water used by households depends on accessibility to water source. Primarily, the quantity of water available and used by households is determined by distance to the water source, quality and cost expended. It has been noted that in many large cities where provision of water is inadequate, there is little or no shortage of fresh water resources. Thus, the paradox of 'inadequacy of supply in the midst of abundance' exists.

Statistics provided by UNICEF (1996) showed that less than 45 percent of Nigerians indicated that their main sources of water are unsafe and inadequate. 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). The lack of clean water and sanitation leads to a wide range of diseases. These diseases associated with lack or inadequate water supply as well as poor sanitation includes cholera and typhoid. The most affected groups are children, immuno-compromised persons and other vulnerable groups such as aged persons.

According to Clasen and Bastable (2003), contaminated drinking water is the main contributor to an estimated 4 billion cases of diarrohea each year, thus, causing about 2.2 million deaths, mostly among children under the ages of 5. Globally, nations face the challenge of contaminated water; hence, it has led to the outcry and need to improve the assessment of the world's water sources, which will impact on health.

Springs, underground water sources, are widely used sources of water. They are considered to be aesthetically acceptable but poor and inadequate protection at the source, as well as, unhygienic household handling practices may lead to its contamination. It is noted that drinking water may become contaminated following its collection from these protected sources and during the storage at homes (Moll *et al.*, 2007).

The city of Ibadan has about twenty-four identified springs which supply clean water to the different communities in and around where they are located (SIP, 2004).

There is dearth of information on quality of spring water from protected sources and the household practices which may contaminate it in Ibadan. This study seeks to breach the gap and gather information on the quality of these protected springs and the household practices that may affect its wholesomeness.

1.3 Justification of the Study

A reliable safe water supply plays an important role in disease prevention, especially by facilitating personal, domestic and food hygiene. Contaminated and poorly managed water sources can contain chemicals, microbiological or radiological hazards which can lead to sickness. Clean, uncontaminated and adequate water supply improves personal hygiene and also aids in combating diseases.

There is a direct link between population growth and stresses on water supply. Continuous population growth will lead to greater water consumption and waste. It is paramount that the challenge of water quantity and quality is addressed as it has direct impact on the health of a nation's citizenry.

This study seeks to assess the quality of drinking water from protected spring sources from four Local Government Areas (LGAs) in Ibadan. It involves assessment of the physico-chemical parameters, and bacteriological characteristics of water from spring sources and storage containers. In addition, prevailing environmental and sanitary conditions of the springs and household water storage containers were assessed. Furthermore, assessment of the effective use of these springs with regards to the optimal, hygienic and consistent use will provide information on their acceptance by the users.

1.4 Objectives

1.4.1 Main Objective

The main objective of this study was to assess thequality of drinking water from the protected springs and household storage containers and the risk of contamination from household water handling practices.

1.4.2 Specific Objectives

The specific objective is to:

1. Assess the prevailing environmental and sanitary status of the springs.
2. Determine the physico-chemical quality of water from spring sources during dry and rainy seasons.
3. Determine the bacteriologicalquality of water from spring sources during dry and rainy seasons.
4. Determine the bacteriological quality of spring water stored in household containers.
5. Determine the risk of water contamination from springs and the household water storage containers.
6. Assess the community user's knowledge on effective utilization of the springs.

CHAPTER TWO

LITERATURE REVIEW

2.1 Hydrologic/ Water Cycle

The hydrologic or water cycle is the constant movement of water above, on, and below the earth's surface. The global hydrological cycle is the set of processes that continually moves water over and through the surface of the earth and both into and through the atmosphere (Karterakis*et al.*, 2007). It is a cycle that replenishes ground water supplies.

As shown in Figure 2.1, the water cycle involves the continuous exchange of water within the hydrosphere, between the atmosphere, soil water, surface water, groundwater and plants. The sun, which drives the water cycle, heats surface water bodies, some of this heated water evaporates as vapor. Hence, rising air currents take up the vapor alongside with water that transpired from plants and evaporated from the soil. The water vapor rises and condensed into clouds at places of cooler temperature. From these clouds, precipitation occurs and falls as snow, rain or hail, which accumulates and later melts and flows as surface run-off back into surface water bodies or percolates into the soil as infiltration. Some water infiltrates deep into the ground and replenishes the aquifer while some seeps back into surface water bodies. The amount of precipitation that infiltrates, versus the amount that flows across the surface, varies depending on factors such as the amount of water already in the soil, soil composition, vegetation cover and degree of slope.

2.2 Freshwater

Freshwater is an important natural resource necessary for the survival of all ecosystems. It is from rain, surface water(lakes, rivers, streams and ice sheets) and groundwater (springs, wells and boreholes).

Freshwater is a renewable source that people can drink or use for their animals and crops. It can only be replenished through the process of water cycle. The source of almost all freshwater is precipitation from the atmosphere in the form of mist, rain and snow (USGS, 2006).

Freshwater in this form contains materials from the atmosphere, the sea and land over which the rain has travelled. In industrialized areas, water from rain, snow or mist is acidic because of dissolved oxides from burning fossil fuels, such as in cars, factories and atmospheric emissions of industries. The major factor that decreases availability of freshwater is population growth. Global water consumption has increased about sevenfold since the beginning of the 20th century. This has been caused both by population growth and by increase of the per capita water use (Kundzewicz, 1997).

There are 3 major sources of fresh water. viz: surface water, rainwater and groundwater.

2.2.1 Surface water

Surface water is any water that travels or is stored on top of the ground. It is water in rivers, lakes or fresh water wetland. It is naturally replenished by precipitation andnaturally lost through discharge to the oceans, evaporation, and sub-surface seepage (HDC, 2011).The only natural input to any surface water system is precipitation andsnowmelt run-off to streams (Figure 2.1).

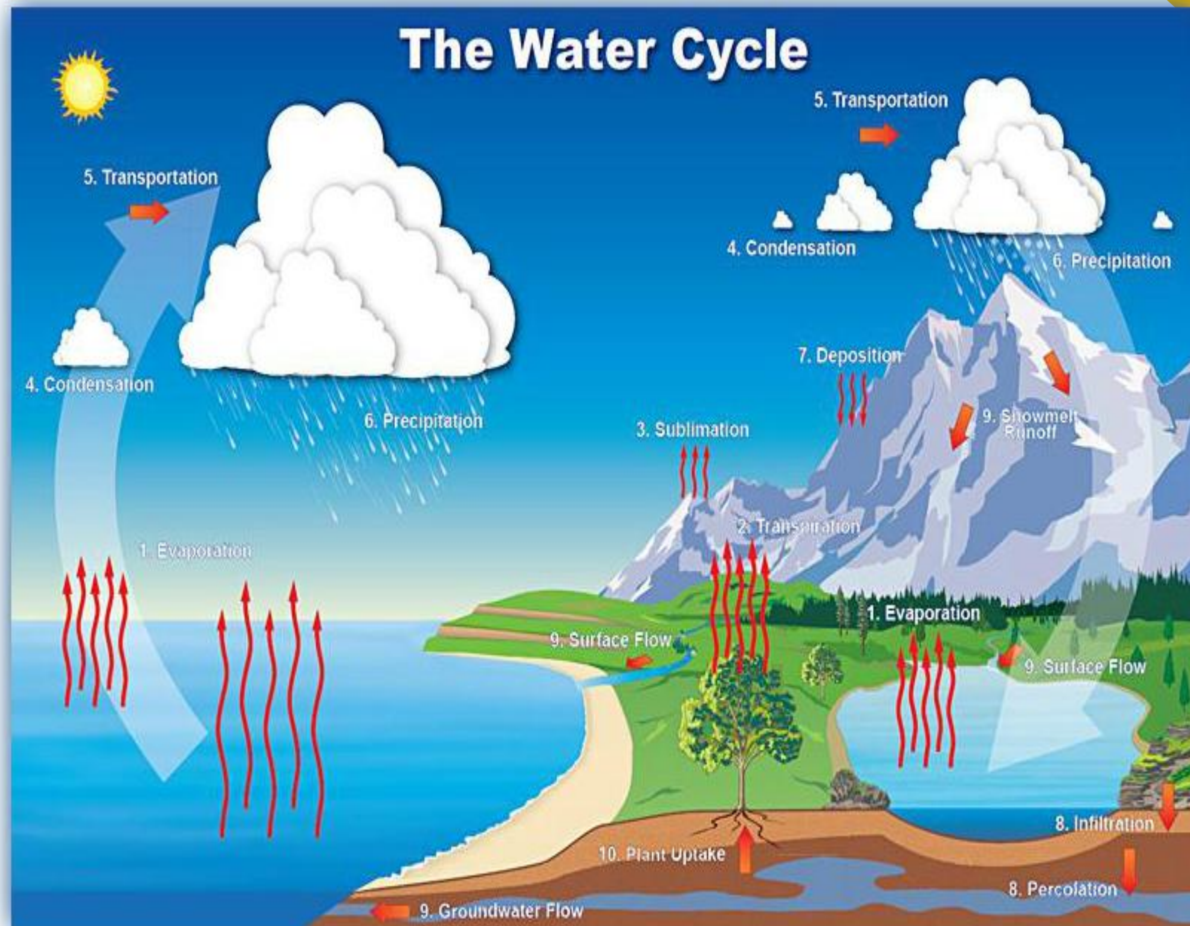


Figure 2.1: The hydrologic/water cycle

Source: Hydrologic Data Collection (HDC) (2011)

Some examples of surface water include rivers, streams, lakes and oceans. Surface water is often used for large urban supply because rivers and lakes can supply a large and regular volume of water.

Surface water often needs treatment before use, because it may be contaminated by faecal and organic material. Rivers and streams have a wide seasonal variation that may affect water quality. In wet seasons, water may carry a high silt load and there is a high risk of faecal contamination at the start of the season as faeces are washed into the river. In dry seasons, the silt load will be lower but the dissolved solids may have a high concentration (WHO, 2006).

2.2.2 Rainwater

Rain is liquid water in the form of droplets that have condensed from atmosphericwater vapor and then precipitated. It is a major component of the water cycle (Figure 2.1) and is responsible for depositing most of the freshwater on the Earth. It provides suitable conditions for many types of ecosystem, as well as water for hydroelectric power plants and crop irrigation.

Rainwater has a complex chemical composition that varies from place to place, as well as from shower to shower and season to season in the same place. It contains some constituents of local origin, and some that have been transported by winds from elsewhere (Carrol, 1962). Chemical constituents in both rain and dry precipitation are added continually to any area of the earth's crust to become part of the chemical weathering environment.

Rainwater is a mixed electrolyte that contains varying amounts of major and minor ions. The sources of these constituents are the oceans, freshwater and saline lakes, landmasses, vegetation, manmade industries, and volcanic emanations (Carrol, 1962).

2.2.3 Groundwater

Groundwater is water that exists in the pore spaces and fractures in rock and sediment beneath the Earth's surface (Nelson, 2006). Most ground water originates from rainfall that has entered the soil. Groundwater is in constant motion, although the rate at which it moves is generally slower than it would move in a stream because it must pass through the intricate passageways between free spaces in the rock. The rate of groundwater flow is controlled by two properties of the rock: porosity and permeability (Nelson, 2006).

The global groundwater volume is 23,400,000 in cubic kilometers and 1.69% of the total water (Gleick, 1993). In comparison to surface water, ground water contains higher concentration of natural dissolved materials. These dissolved materials usually depends on the composition and solubility of earth`s material that the ground water is in contact with and also the length of time it has stayed underground.

2.3 Groundwater Sources

Groundwater is an important source of freshwater which is considered to be the most acceptable if handled well. It is the water that is found underground, saturating the pore spaces and fractures of rocks beneath the earth's surface. The origin of groundwater is from rainfall and snow, as depicted in the hydrologic cycle in Figure 1. When it rains or snow melts, some of the water evaporates, some are lost as transpiration, while some of the water flow overland collecting in streams and other sources, hence, forming surface water. The remaining water infiltrates and percolates into the ground filling the pores and cracks of soils and rocks. It moves down to the unsaturated zone and finally to the saturated zone, where water moves through the aquifer to springs from where it is drawn (USGS, 2006).

Water found in the saturated zone is known as groundwater. Since groundwater is supplied mainly by percolation from the surface, anything which increases the surface supply of a region increases the groundwater of the region (Synd, 1922). Examples of such are the rise of the water table during irrigation season and increase of water in wells during the rainy seasons.

There are three main types of groundwater. They include springs, boreholes and wells.

2.3.1 Spring as a type of groundwater source

A spring is a natural groundwater source. It is the point at which groundwater appears on the surface. Sci-tech encyclopedia defines a spring as a place where groundwater discharges upon the land surface because the natural flow of groundwater to the place exceeds the flow from it. Britannica encyclopedia defines a spring as an opening at or near the Earth's surface where water from underground sources is discharged.

Springs are favoured water sources as they often produce high quality water, are inexpensive to protect and do not require a pump to bring the water to the surface. In Nigeria, springs are regarded as important groundwater sources especially in the peripheral and rural areas. They are important not only because they form sources of local water supplies but also because they support perennial flows in large rivers (Areola, 1980). The water quality of springs varies greatly because of factors such as the quality of the water that recharges the aquifer and the types of rocks the groundwater comes in contact with. Thus, the spring water quality represents the general water quality of the groundwater.

Most times, springs occur naturally and they are considered safe sources of drinking water. Figure 2.2 shows the geological formation of springs. When properly protected and maintained, springs provide consistent supplies of safe and wholesome water with little or no microbial load. However, during the collection, transportation and storage, contamination could occur. Though spring water is considered to be aesthetically acceptable for domestic use, presence of poorly designed pit latrines, poor wastewater management, poor solid waste management as well as poor and inadequate spring protection, may lead to contamination of water from the springs with pathogenic bacteria.

If a spring occurs uphill of the community to be served, it can be connected to a gravity-fed piped distribution system. If the spring occurs downhill of the target community, the water can be pumped up to a storage tank. Springs close to small communities where a piped system is not feasible can be protected and allowed to overflow from the spring box permanently or be connected to a storage tank fitted with a low-lift hand pump (WHO, 2009).

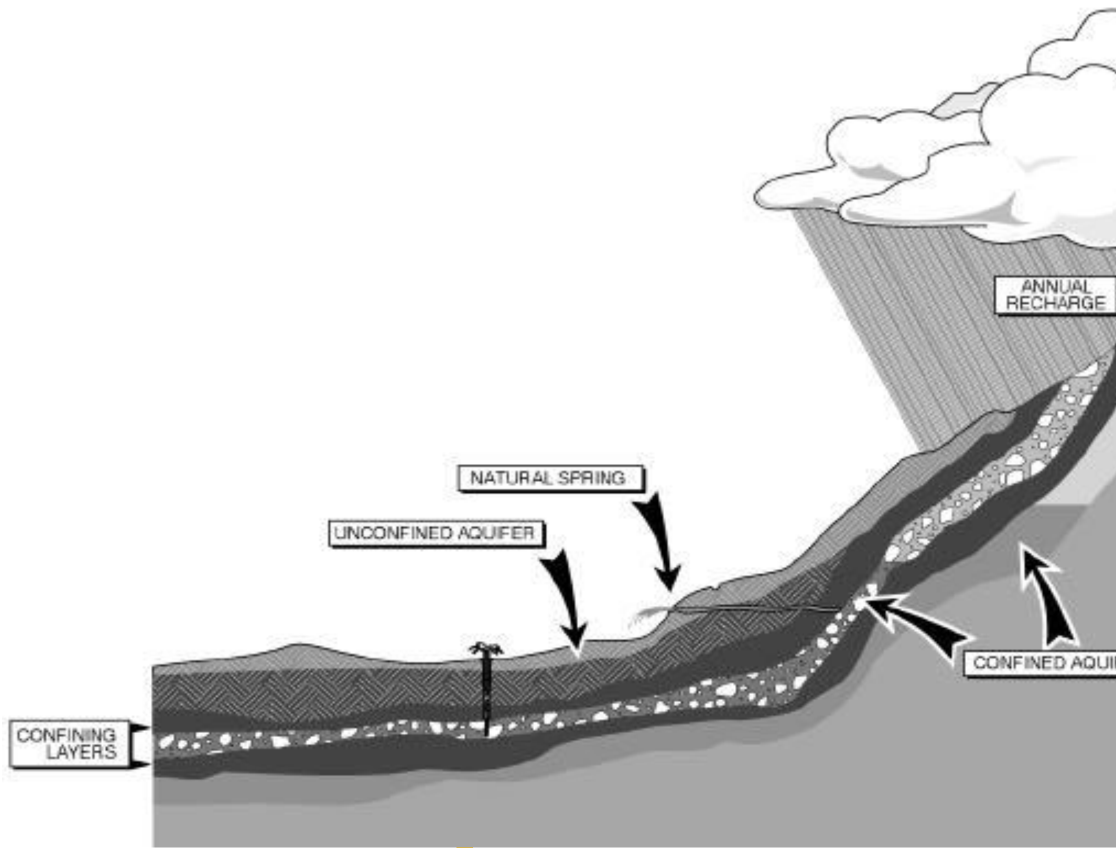


Figure 2.2: Geological formation of springs

Source: UFTREEO Center, 1998

According to USEPA (1999) there are two types of springs depending on their occurrence. Although these spring types defer in their occurrence, their formation is similar.

1. Gravity springs - These occur where groundwater emerges at the surface because an impervious layer prevents it from seeping downwards or the water table is at the same height as the land. This type of spring usually occurs on sloping ground, as shown in Figure 2.3, and its flow changes with variations in the height of the water table. The flow tends to vary with the time of year.
2. Artesian springs - Artesian springs occur where groundwater emerges at the surface after confinement between two impervious layers of rock. The groundwater is held under pressure and comes to the surface because of a natural break in the rock. The flow is very nearly constant during the year (Figure 2.4).

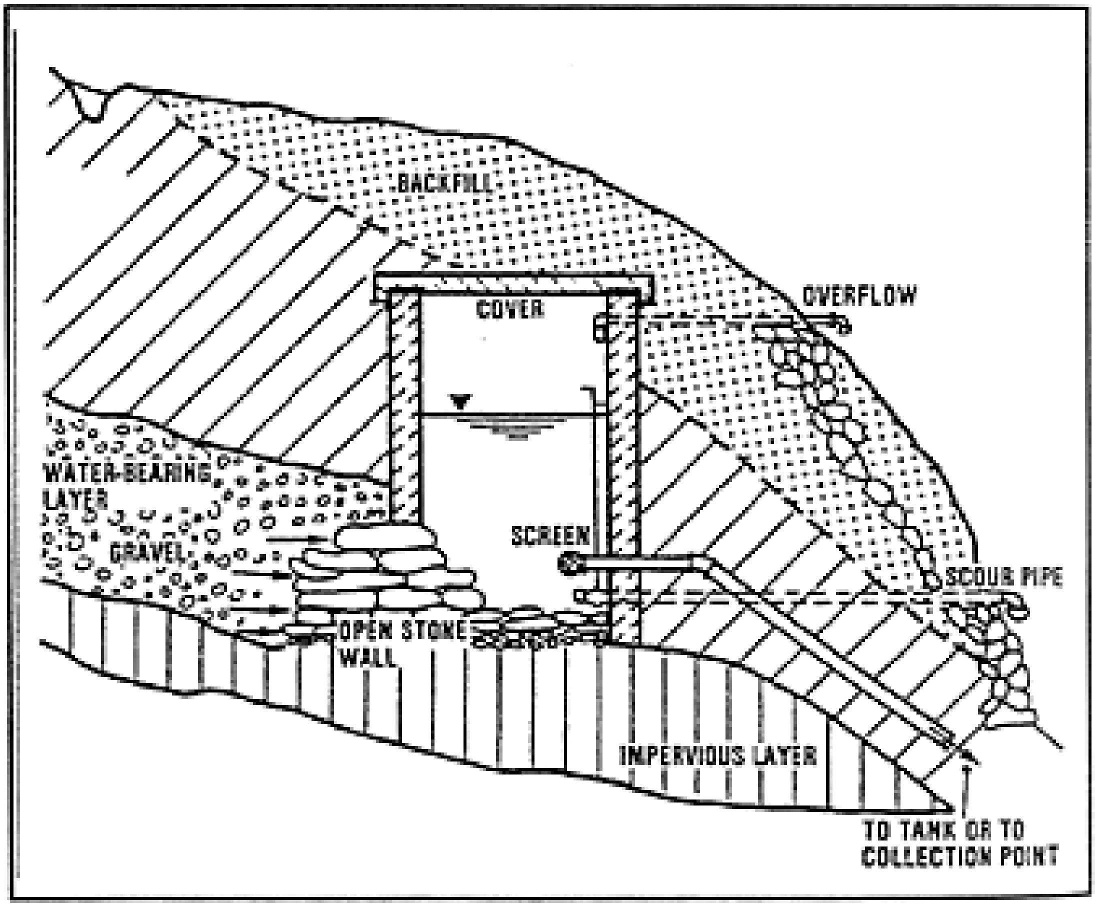


Figure 2.3: Gravity spring

Source: UNESCO, 1991

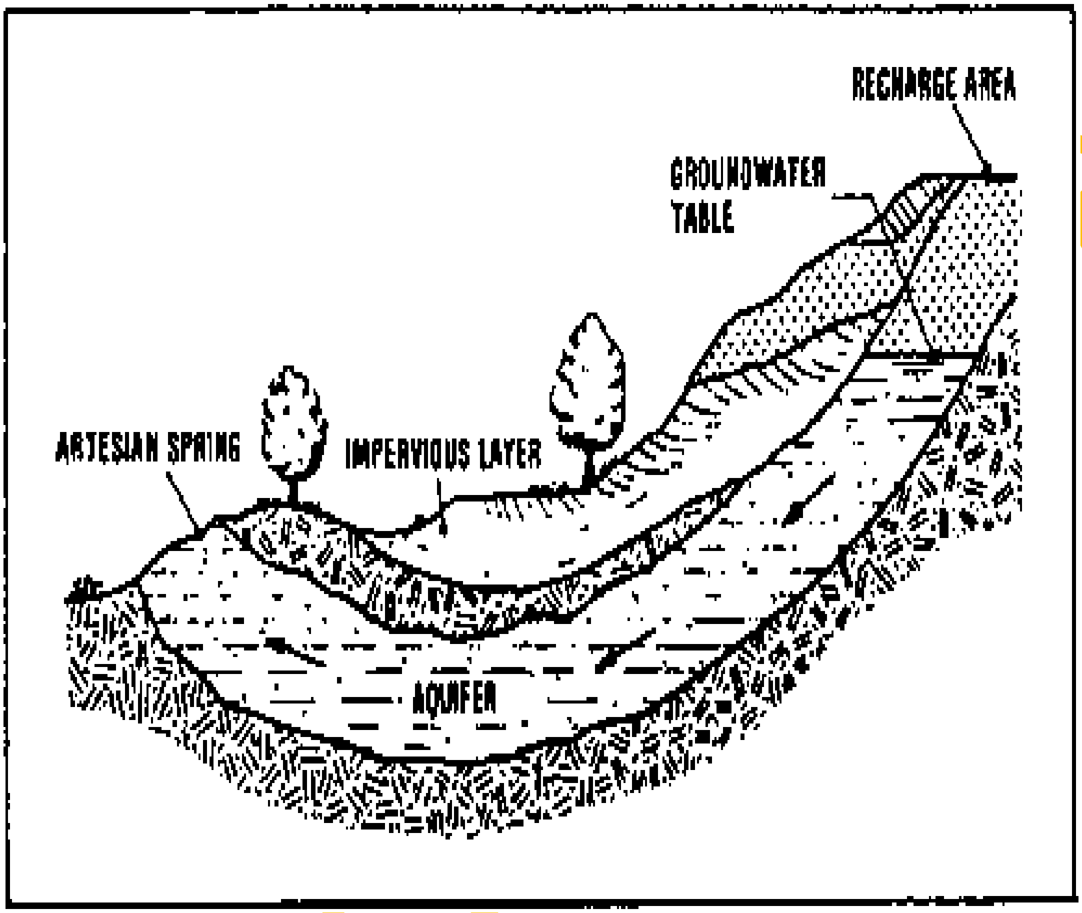


Fig 2.4: An Artesian Spring

Source: WHO, 1996

2.4 Groundwater Flow

Groundwater flows through water-bearing formations, known as aquifers at different rates. It is in constant motion, although the rate of water flow is slower than in surface water such as streams. As is the case for surface water, groundwater flows from higher elevations (or pressures) toward lower elevations (or lower pressures). Groundwater flow is usually towards a groundwater discharge area (Bruhel, 2006). The slow water flow is because it must pass through the intricate passageways between free spaces in rocks.

According to Nelson, 2006, the rate of groundwater flow is controlled by two properties of the rock: porosity and permeability.Porosity is the percentage of the volume of the rock that is open space (pore space). This determines the amount of water that a rock can contain, while, permeability is a measure of the degree to which the pore spaces are interconnected, and the size of the interconnections.

2.5 Groundwater Quality

Groundwater quality comprises the physical, chemical and biological qualities of groundwater. Jain *et al.* (1995) described groundwater quality as the result of all the processes and reactions which act on the water from the moment of condensation to the time of its discharge by either wells or springs; and this varies from place to place and with the depth of the water table.

Bruhel (2006) opined that the quality of groundwater reflects substances that are dissolved or suspended in the water. Groundwater usually contains higher concentrations of natural dissolved materials than surface water. These materials dissolved in the water reflects the composition and solubility of the earth materials (soil or rock) that the groundwater is in contact with as well as the time that it has been in the subsurface.

Groundwater quality also depends on the composition of the recharge water, the interactions between the water and the soil, soil-gas and rocks with which it comes into contact, and the residence time and reactions that take place within the aquifer (Jain *et al.,* 1996). Thus, variations may exist in the groundwater quality in the same area where rocks of different compositions and solubility occur.

This unique feature of groundwater which renders them suitable for public water supply is their excellent natural quality which is free from pathogens, colour, and turbidity; hence, leading to its consumption without treatment (Jain *et al.*, 1996).

Naturally, groundwater contains mineral ions. These ions are obtained from soil particles, sediments, and rocks as the water travels along mineral surfaces in the pores or fractures of the unsaturated zone and the aquifer.Some dissolved solids may have originated in the precipitation water or river water that recharges the aquifer (Harter, 2003). These dissolved solids found in groundwater are as a result of the physical property of water as an excellent solvent, hence, it dissolves and carries most solids as it flows. The quality of ground water depicts the quality and types of rocks found underground.

As groundwater flows through an aquifer, it is naturally filtered. The sand and silt are filtered off through the different layers of rock. This filtering, combined with the long residence time underground, means that groundwater is usually free from disease-causing microorganisms. The high mineral content, fewer microbes and particulates gives groundwater its constant cool temperature (Dietrich, 2006). Microbial matter is also a natural constituent of groundwater. Just as microbes are ubiquitous in the environment around us, they are very common in the subsurface, including groundwater.

Chemical constituents found in ground water depend in part on the chemistry of precipitation and the recharge of the water. The natural quality of groundwater differ from surface water because the temperature and other parameters are less variable over time unless in instances of pollution. Groundwater from depth and confined aquifers is usually microbially safe and chemically stable in the absence of direct contamination; however, shallow or unconfined aquifers can be subject to contamination from discharges or seepages associated with agricultural practices (e.g., pathogens, nitrates and pesticides), on-site sanitation and sewerage (pathogens and nitrates) and industrial wastes (WHO, 2006).

2.6 Protection of Groundwater Sources

Protection of groundwater sources is the prevention of pollution. Groundwater sources are often of good quality and may only require source protection and disinfection. Source protection provides the first barriers in protection of drinking-water quality (WHO, 2006). Wellhead protection is an example of groundwater protection, the prevention of well water contamination.

Source water protection can be a cost-effective approach to safeguarding a community's drinking water supplies. By decreasing the contamination of the source water, the amount of treatment required is reduced. This may reduce the production of treatment by-products and minimize operational costs. The benefits accruing from source protection is better appreciated when compared to the cost (quantifiable and non-quantifiable) of failing to protect the water source (Ainsworth and Jehn, 2005).

Howard (2002) categorised factors which may pose as risks to groundwater sources. These factors enumerated below must be considered before groundwater protection because they may compromise the quality of groundwater.

1. Hazard factors - These are sources of faecal material located so that they constitute a risk to the groundwater. An example is a pit latrine overlying an aquifer and close to a water abstraction point.
2. Pathway factors - These are potential routes by which contamination may enter into the water supply. Pathway factors include cracks in the lining of boreholes, improperly sealed apron surrounding the headwall of a dug well or borehole, and eroded backfilled area of a protected spring. Pathway risk factors often result from poor operation and maintenance.
3. Indirect factors - These are factors that represent lack of a control measure to prevent contamination and therefore increase the likelihood of a hazard or pathway developing but do not themselves represent either a hazard or a pathway. An example of this is a fence around the water source. The absence of a fence will not lead directly to contamination, but may allow animals or human to gain access to the source and create either a hazard (through defecation) or a pathway (through causing damage to the source).

2.7 Spring Protection

Spring protection is prevention of springs from contamination. Protected springs are considered an improved water source by the World Health Organization and thus are counted towards the millennium development goal (MDG) targets. Spring protection is used to provide safe water supply. Persell and Almeida (2008) reported that improvement in water quality will be achieved by testing and disinfecting water from protected springs to meet the UNICEF/WHO standards. As compared with treatment of contaminated water, the technique of spring protection is cost effective in the long run.

Spring water is generally free from microbes and often safe to drink, after it has being filtered through soil and rock, however, it may be rapidly contaminated when it emerges at the surface. Contaminated surface water nearby or wild and domestic animals, as well as people who collect or use the water from the spring may pose a threat to the quality of spring water. The impact of spring protection is estimated on source water quality, household water quality, child health, and on household water collection choices and other health behaviors (Kremer *et al.,* 2006).

Protection seals off the source of a naturally occurring spring and encases it in concrete so that water flows out from a pipe rather than seeping from the ground where it is vulnerable to contamination from runoff. Spring protection consists of construction of a spring box around the point where water emerges, hence, preventing direct contamination (WHO, 1997; Howard *et al.,* 2001). A properly protected spring is developed underground and the water channeled to a sealed spring box (Parrott *et al.,* 1996). Spring protection involves protecting the outlet of the spring. The outlet should be surrounded by a fence to keep animals and other polluting sources from contact to the spring. The ground surface around the spring should be constructed to keep all surface drainage from passing into or over the spring outlet. The outlet should be further protected by being surrounded with a box, as shown in Figure 2.5 which excludes dust, vermin and larger animals which may enter the spring (Synd, 1922).

2.8 Provision of Sustainable Improved Water Supply

In the Millennium Declaration, the heads of state gathered at United Nations Headquarters in New York in September 2000 resolved, under the heading "Protecting our Common Environment," to stop the unsustainable exploitation of water resources by developing water management strategies at the regional, national, and local levels, which promote both equitable access and adequate supplies (UN, 2000).

The UN-Habitat (2003), reported that problems of water stress are caused by the increase demand for water as the city's population, intensive municipal agriculture, commercial and industrial uses grow. Water resources management strategies translate better provision of potable water from other sources such as wells and natural springs, other than tap water.

To alleviate the shortages in water supply, various planning approaches have evolved. The recent response of the United Nations Centre for Human Settlement (UN-Habitat) and the United Nations Development Programme (UNDP) was the launching of the Sustainable Cities Programme (SCP) using the Environmental Planning and Management (EPM) process (UN-Habitat-SCP 2001). As reported by SIP (2004), the main objective of this programme was to improve environmental factors by decentralizing the responsibility from the Federal to the local government, thus, allowing the identification of environmental problems, funding, designing and management of projects through local participation and involvement of the community users.

2.9 Impact of Improved Water Supply.

The primary long-term goal of improved water supply is to improve health, productivity and living conditions. Narayan-Parker (1993) identified a series of indicators for measuring the impact of protected springs. These indicators are geared towards the maintenance of good health for the community users. In addition to these indicators which measure long-term benefits; immediate results such as improved health care and availability of good quality water supply, should also be experienced. Another immediate benefit is increased and available time. This increased time is then utilized for child-care, food preparation and productive activity (Howard and Bartram, 2003).

The three main indicators used to measure the impact and applicability of protected springs as proposed by Narayan-Parker (1993), is as follows:

1. Sustainability

Sustainability is the ability to maintain the efforts and the derivable benefits at the communities without the detrimental effects on the environment (Narayan-Parker, 1993). This indicator implies a problem-solving capacity. There are some sub-indicators used to check the progress of improved water supply. These sub-indicators are:

a. Water quality at the source

b. Maintenance of the facility at source

c. Knowledge and skills of users

2. Effective use

Effective use is the optimal, hygienic and consistent use of water to maximize benefits and minimize negative consequences over an extended period of time. The sub-indicators that measure effective use place central attention on people, especially women and children because they are the primary users of domestic water.

a. Optimal use – This is the use of facilities to maximize economic benefits. This involves number of users, quantity of water used and time taken to use the protected springs.

b. Hygienic use – This is the improvement of drinking water quality after it has been withdrawn from the protected springs. It involves water quality at home, transport and storage practices, home practices to improve water quality and personal hygiene.

c. Consistent use – This is the use of protected springs throughout daily and seasonal cycles, over the life of these facilities. It involves the pattern of daily and seasonal use.

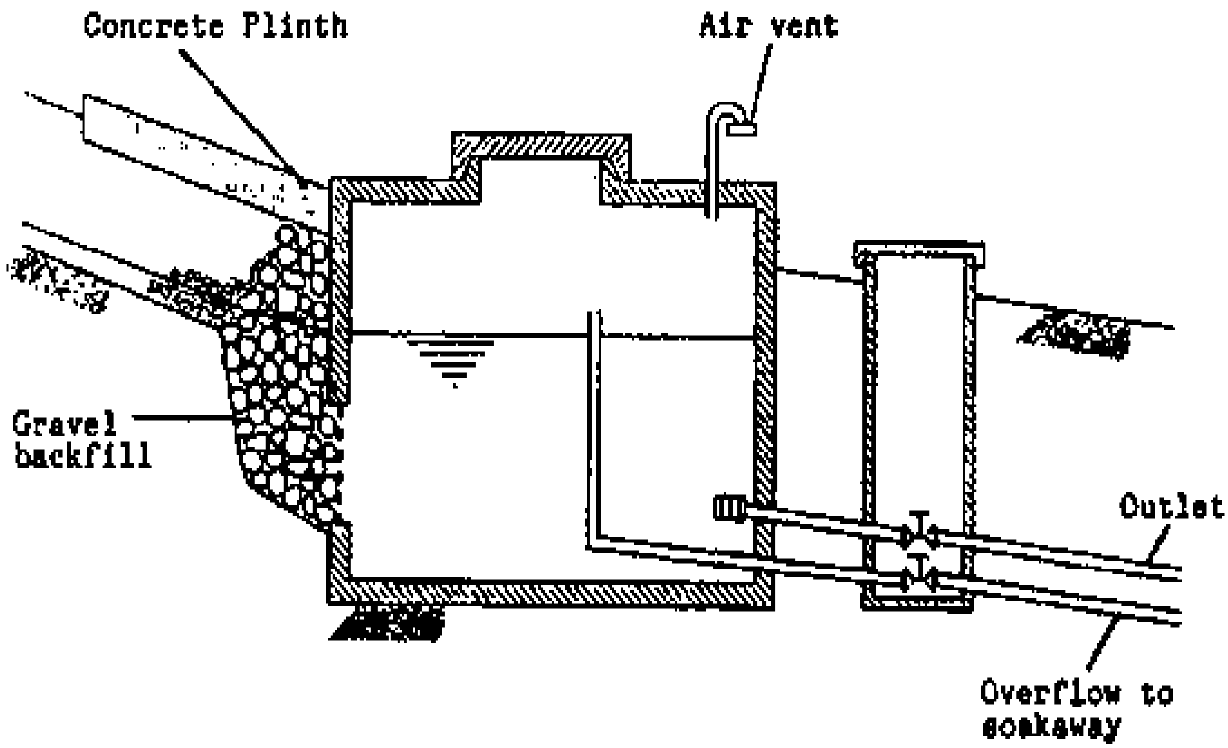


Fig 2.5: Spring Protection Box

Source: WHO, 1996

3. Replicability

Replicability is the ability to duplicate the processes and benefits of protected springs in locations where the springs have not been protected. This indicator is a true test of the values of development. Replicability of a programme is more likely when there is optimal use of such projects. Thus, projects should be based upon the use of local people, local skills and the knowledge of the people which such developments are set up for. The sub-indicators that measure replicability are:

a. Proportion and role of specialised personnel – In pilot projects, there should be a high input of specialised personnel, but when these projects have been completed, they should be replicated, with a decline of input from the specialists while existing staff, who are locals should be utilised.

b. Established institutional framework – There should be no by-passing of an already existing organization, and there should also be an increased inter-agency collaboration

2.10 Water Pollution

Increasingly, surface and groundwater sources are being polluted by pesticides, industry and untreated household waste water (WHO and UNICEF, 2008). There are many activities that affect the supply of clean, safe and adequate water. These are natural, man-made and also natural activities exacerbated by man-made causes.

Amongst the natural causes, one of the biggest causes affecting the supply of clean and safe water is the buildup of sediments over time in surface water, which is as a result of wash-off of soil, silt and organic debris into water bodies by rain. This natural cause is made far worse when human activities add an extra burden of wash-off from agricultural deposit, industrial effluent discharge and dumping of waste.

Pollution caused by man-made activities which pose major threat to the supply of safe water is from agriculture and industries. Run-off of chemicals (such as weed-killers, pesticides and fertilizers used for agricultural purposes) into water bodies has detrimental effect to both human and water-based living creatures. This greatly impedes the supply of clean water leading to fast reproduction of algae, hence, reducing the oxygen level in water.

Non-degradable industrial waste discharged into surface waters is very hazardous and threatens supply of clean water. High levels of heavy metals in water sources are as a result of run-off of these industrial products. Petrochemical industries have been implicated in oil- rich states in Nigeria. This has led to the massive destruction of aquatic life and lack of clean water. Industrial discharge of non-treated effluent into drains which eventually empty into surface waters is another source of industrial pollution jeopardizing the supply of safe water.

Sewage disposal is another major cause of man-made water pollution. This is a problem encountered in developing countries because of lack of proper human waste disposal facilities. UN (2000) estimated that just under half the population of the earth (44%) was living with unsatisfactory sewage disposal systems. Sewage also poses major problems during disasters when flood waters swamp drains.

2.11 Groundwater Pollution

Groundwater pollution is defined as an undesirable change in groundwaterquality resulting from natural or human activities (Harter, 2003). It is a modification of the physical, chemical and biological properties of groundwater.

Natural pollution of groundwater occurs when rainfall that has soaked the ground comes in contact with buried waste or other contaminants and chemicals and seeps into groundwater.Human activities can also alter the natural composition of groundwater through the disposal or seepage of chemicals andmicrobial matter on the land surface into soils, or throughinjection of wastes directly into ground water. Although there are many common sources of contaminants, such as fertilizers and animal wastes, groundwater differs from surface water, because groundwater is protected naturally (Harter, 2003).

Pollutants that are fully soluble in water and of about the same density will spread through the aquifer at a rate related to the groundwater flow velocity, but pollutants denser than water will be filtered through sand, stones and silt. Thus, even though the ground is an excellent mechanism for filtering out particulate matter, such as leaves, soil and bugs, dissolved chemicals and gases can still occur in large enough concentrations in ground water to cause problems.

There is usually a delay between a pollution incident and detection of the contaminant at the point of water abstraction because movement in the unsaturated zone and flow in the aquifer are often slow. Groundwater often spreads the effects of dumps and spills far beyond the site of the original contamination. Contamination of groundwater is extremely difficult to control; it can render the water unsuitable for use and sometimes impossible to clean up. Over burden of the population pressure, unplanned urbanization, unrestricted exploration policies and dumping of the polluted water at inappropriate place enhance the infiltration of harmful compounds to the ground water. Substances that can pollute groundwater can be divided into two. These are naturally occurring pollutants and pollutants produced from human activities (Pandey and Tiwari, 2008).

Naturally occurring contaminants include:

1. Sea water intrusion – In areas where groundwater is overexploited, sea water moves to the aquifer to maintain a balance, thus, the quality of the groundwater begins to deteriorate and the salt concentration increases.
2. Geological formations- The chemical composition of groundwater is dependent on the immediate minerals around the vicinity of the groundwater. For environments containing the natural mineral substances found in rocks or soils such as iron, manganese, chlorides, fluorides, and sulfates, they become dissolved in and contaminate groundwater.
3. Lake/river – aquifer relation – There is a relationship that exists between the lake, river and aquifer, such that if any is polluted, there is a resulting negative impact on the others.

Pollutants from human activities can be broadly divided into 3:

1. Municipal waste disposal – This is one of the major problems encountered in developing countries. Community and residential waste disposal, including septic systems and improper storage and disposal of chemicals in our homes contribute to ground water contamination. Other sources of pollution include poor sewerage systems, municipal wastewater discharge and dump sites situated near a groundwater source. This could lead to an increase in the microbial load (WHO, 2006).
2. Industrial disposal– This is common in areas where factories are located. Such companies or factories dispose their unfiltered waste, which infiltrates and seeps into the groundwater. Included in this category are mechanic workshops and leakage of petroleum products (like beneath fuel filling stations). The groundwater quality is usually high in heavy metals.
3. Agricultural pollutants– The use of agricultural products such as pesticides and fertilizers is implicated. Agricultural pollutants are one of the most widespread human

activities. Agricultural runoff can lead to increased challenges to treatment (WHO, 2006).

4. Cemeteries are another source of pollution for groundwater. They are often located at the top of hills, and are thus up gradient from the local groundwater flow. Decomposing bodies within the cemetery release bacteria, breakdown products from decay and chemicals used for embalming into the local groundwater supply (Nelson, 2006).

There are two categories of groundwater pollution - point sources and non-point sources. The point source pollution originates from a point, but the deleterious impact experienced is widespread. Some examples of point source pollution include: landfills, leak and spills of petroleum product and leaking septic tanks. The non-point source pollution is dispersed over broad areas. This category of pollutants constitutes a large source of potential pollution. Some examples are infiltration from farm land treated with pesticides and fertilizers.

Chery (1986) enumerated some examples of point and non-point sources of pollution.

1. The point sources of pollution include:

a. On-site septic systems
b. Leaky tanks or pipelines containing petroleum products
c. Leaks or spills of industrial chemicals at manufacturing facilities
d. Underground injection wells (industrial waste)
e. Municipal landfills
f. Livestock wastes
g. Leaky sewer lines
h. Chemicals used at wood preservation facilities
i. Mill tailings in mining areas
j. Fly ash from coal-fired power plants

k. Sludge disposal areas at petroleum refineries
l. Land spreading of sewage or sewage sludge
m. Graveyards
n. Road salt storage areas
o. Wells for disposal of liquid wastes
p. Runoff of salt and other chemicals from roads and highways
q. Spills related to highway or railway accidents
r. Coal tar at old coal gasification sites
s. Asphalt production and equipment cleaning sites

2. The non-point sources of pollution include:

a. Fertilizers on agricultural land
b. Pesticides on agricultural land and forests
c. Contaminants in rain, snow, and dry atmospheric fallout

2.12 Water Use

For the past century, water use has grown more than twice the rate of the population (UN, 2008). The current gulf in water use between rich and poor countries is wide—people in industrialized countries use 30–50 times more water than people in developing countries (UN/WWAP, 2003).

Uses of water occur majorly at the household levels for drinking, cooking, eating, bathing and laundry; others may occur away from the home, example, in industries that use water as a raw material, laundry services, agriculture, transport and recreation.

White *et al.* (1972)reported that there are three (3) types of water use. The water uses 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 and lawn watering).

A fourth category 'Productive use' was suggested by Thompson *et al.* (2001) which is of particular relevance to poor households in developing countries. This fourth category includes brewing, animal rearing, construction and small-scale horticulture. The first two categories- consumption and hygiene- as suggested by White *et al.* (1972) has direct consequences on health both in relation to physiological needs and in the control of diverse infectious and non-infectious water-related diseases.

2.13 Benefits of Groundwater Use

Groundwater is a highly useful and important fresh water source. It is often the primary source of water supplies for most communities. Groundwater development has provided significant socioeconomic benefits, in addition to the public health gains. This is due to the consequent reduction of waterborne diseases and infections resulting from the use of unclean water. Groundwater usage has increased significantly over the last decades. This is primarily due to its widespread occurrence, overall high quality and reliability. Fresh water is limited, but its demand increases with increasing population. In places where surface water is unavailable, insufficient, inconvenient nor feasible for consumption, groundwater has the potential to meet such demands if handled well. It is believed that groundwater accounts for 88% of safe drinking water in rural communities, where the population is dispersed and the infrastructure needed for treatment and transportation of surface water does not exist (Kumar, 2004).

This vastly under-valued water resource is considered as one of the keys to solving the world water crisis. It represents 97% of the planet's accessible fresh water reserves (UNESCO, 2006). The enormous economic benefits are felt in different sectors, such as agriculture and industries. It supports agriculture by providing very significant quantities of water for irrigation, especially in regions where the climate is dry and crop production without irrigation is not feasible. Groundwater maintains soil moisture, stream flow and wetlands. It is also ecologically important.

Although, groundwater is a highly useful and abundant resource, however, over-use can cause major problems to human users and to the environment, such as lowering of water table, which could result in drying up of springs (Nelson, 2006). Sustainable use of groundwater resources depends on measuring the balance between the current rate of extraction and the rate of recharge.

In summary, groundwater serves a variety of needs (FAO, 2008). These needs include:

1. Agriculture – This is by far the most intensive consumer of groundwater resources, especially through irrigation.
2. Industry - This is the second largest consumer of groundwater. Most industries that use water as one of their raw materials, for example the cement and food processing industries have boreholes.
3. Household needs for drinking, hygiene and food preparation. These needs are met by groundwater resources.
4. Natural environment relies on groundwater as the main source for the base flow of shallow aquifers and wetlands, representing an effective buffer against droughts.

2.14 Drinking Water Quality

The quality of water that is consumed is well-recognised as an important transmission route for infectious diarrhoeal and other diseases (WHO, 1993a). Sobsey (2006), states that contaminated drinking water contributes to the global burden of waterborne infectious disease. Consumption of water containing toxic levels of chemicals may also lead to health-compromising conditions.

Water for human consumption must be free from all objectionable odour, turbidity, taste, enteric pathogenic bacteria or their indicators and must not fluctuate in its quality (Dawson and Sartory, 2000). Most coliforms are found in large numbers in the intestinal flora of warm-blooded animals, and thus appear in the faeces. As a consequence, high concentrations of coliform detected in drinking water are used as an index for the presence of entero-pathogens (Rompré*et al.*, 2002). The faecal bacteria found in drinking water are an indication of a risk from disease presented to consumers (Crampton, 2005).

2.14.1 Phyisco-chemical and Bacteriological Qualities of Drinking Water.

Water quality is defined in terms of the chemical, physical and biological contents of water. Water quality guidelines provide basic scientific information about water quality parameters and relevant toxicological threshold values to protect specific water uses (Lawson, 2011).

The quality of ground water depends on various chemical constituents and their concentration, which are mostly derived from the geological data of the particular region. Industrial waste and the municipal solid waste have are the leading causes of pollution of surface and ground water.

The availability of good quality water is an indispensable feature for preventing diseases and improving quality of life. It is necessary to know details about different physico-chemical parameters. Due to increased human population, industrialization, use of fertilizers and man-made activity water is highly polluted with different harmful contaminants. It is necessary that the quality of drinking water should be checked at regular time interval, because use of contaminated drinking water could lead to water borne diseases.

2.14.2 Heavy metals in drinking water

The effects of heavy metals in water range from beneficial through troublesome to dangerously toxic (APHA, 1989). While some metals are essential, some have deleterious effect to health depending on the concentration.

According to APHA, 1989, Atomic Absorption Spectrophotometry (AAS) is a method used in the determination of heavy metals. Its use is based on the phenomenon that the atom in the ground state absorbs light of wavelengths that are characteristic to each element when light is passed through the atoms in the vapour state. Because this absorption of light depends on the concentration of atoms in the vapour, the concentration of the target element in the water sample is determined from the measured absorbance.

The AAS analyses the light beam transmitted through the absorbing medium which is placed between the source of radiation and a detector. The light beam is directed through the flame, into a monochromator and on to a detector that measures the amount of light absorbed by the atomized element in the flame. Each metal has its own characteristic absorption wavelength; a source lamp composed of that element is used. The amount of energy of the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample.

2.15 Drinking Water Quality Standards

Drinking water quality standards ensures the safety of the drinking water supplies and the protection of the health of the general public. The values depicted in Table 2, represent the concentration of a constituent that does not exceed tolerable risk to the consumer over a lifetime of consumption.

In the 'Guidelines for Drinking-Water Quality', values for chemical contaminants are based on the assumption of a 60 kg adult consuming 2 litres of drinking water per day (WHO 2003). For the purpose of this research, the results of the analysis are been compared to the WHO and SON standards.

2.16 Household Drinking Water Supplies

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. Groundwater is a relatively safe source of potable water, but may be contaminated during storage and collection from containers. In its Guidelines for Drinking-Water Quality, WHO defines domestic water as "water used for all usual domestic purposes including consumption, bathing and food preparation" (WHO, 1993b).

The quantity and quality of water delivered and used for households is an important aspect of domestic water supplies. It influences hygiene and therefore significant health gains occur largely when water is available at household level (Howard and Bartram, 2003). Water is vulnerable to contamination by bacteria at many points in its journey from reservoir to mouth. Water stored in the home may become contaminated during handling if it is not stored and protected properly. Thus, water handling is pertinent, as water may become contaminated before consumption.

Table 2.1: Characteristics for Drinking Water and the Associated Health Impact.

Parameters	Unit of measurement	WHO	SON	Health impacts
Temperature	^oC	Ambient	Ambient	None
pH		6.5-8.0	6.5-8.5	None
Total solids	mg/l	-	-	-
Total dissolved solids	mg/l	500	500	None
Electrical conductivity	µS/cm	400	1000	None
Turbidity	NTU	5	5	None
Total hardness	mg/l	100	150	None
Alkalinity	mg/l			
Calcium	mg/l	-	-	-
Nitrate	mg/l	45	50	Cyanosis and asphyxia (blue-baby syndrome) in infants under 3 months
Phosphate	mg/l	0.03		
Sulphate	mg/l	200	100	None
Iron	mg/l	0.3	0.3	None
Manganese	mg/l	0.1	0.2	Neurological disorder
Lead	mg/l	0.01	0.01	Cancer, interference with Vitamin A metabolism, affect mental development in infants, toxic to the central and peripheral nervous system.
Zinc	mg/l	5	3	None
Total coliform	10MPN/100ml	10	10	Indication of microbial flora
E. coli	MPN/100ml	0	0	Urinary tract infection, bacteriaemia, meningitis, diarrhoea (one of the main cause of morbidity and mortality among children), acute renal failure, haemolytic anaemia

Sources: WHO (1993b) and SON (2007)

The health gains accruing from investments in water are compromised by the fact that water often becomes contaminated during distribution or transport to the home, and during storage and handling within the home (Nath*et al*, 2006). Contamination after collection and during transportation and storage is increasingly being recognised worldwide as an issue of public health importance (Lindskog and Lindskog, 1988; Genthe and Strauss, 1997). Water collected for domestic use often becomes re-contaminated (if it was contaminated initially) or further contaminated by unsafe consumer storage and handling practices at the household level.

Microbial contamination of collected and stored household water is caused not only by the collection and use of faecally contaminated water but also by contamination of initially microbiologically safe water after its collection and storage. Regardless of whether or not collected household water is initially of acceptable microbiological quality, it often becomes contaminated with pathogens of faecal origin during transport and storage due to unhygienic storage and handling practices (WHO, 2009).

Factors contributing to this problem are unsanitary and inadequately protected (open, uncovered or poorly covered) water collection and storage containers, the use of unsanitary methods to dispense water from household storage vessels, including faecally contaminated hands and dippers, lack of protection against contamination introduced by vectors (flies, cockroaches, rodents, etc.) and improper cleaning of vessels to prevent biofilm formation and accumulation of sediments and pathogens (Sobsey, 2002 and Wright *et al.*, 2004).

Collection, storage and handling of drinking water are one of the major risk areas with respect to domestic hygiene. Water quality for domestic use is an important determinant of personal and domestic hygiene (Nath, 2003). The method of water storage can impact on the quality of water (Crampton, 2005). Many factors have been implicated in the contamination of water stored in homes, some of which are: allowing domestic animals to have access to stored water, collecting water with different dirty ladles/containers, dipping hand into the water to fetch from the storage containers.

A common hazard of household water is contamination by potentially harmful bacteria and other microorganisms. Short term gastrointestinal disorders and illnesses such as gastro-enteritis, giardiasis, typhoid, dysentery, cholera, and hepatitis have been linked to water contaminated by microorganisms (Parrott *et al.*, 1996).

Certain practices have been identified which may be associated with the contamination of household water or the resultant diseases. Vessel characteristics such as large-mouths used for water collection and storage (Mintz*et al*, 1995), transferring water from collection to storage vessels (Lindskog&Lindskog, 1988) and accessing water by dipping hand-held utensils rather than via a tap or by pouring (Swerdlow*et al.* 1997). After contamination has occurred, the time or period the water spends in the storage vessel before consumption (Roberts *et al*, 2001) may also influence the survival of the bacteria. Other factors contributing to greater risks of microbial contamination of stored water are higher temperatures, increased storage times, higher levels of airborne particulates (dust storms), inadequate hand washing and the use of stored water to prepare weaning and other foods that also become microbiologically contaminated and contribute to increased infectious disease risks (Dunne, 2001; Iroegbu*et al.*, 2000; Knight *et al.*, 1992; Luby*et al.*, 2001).

Improvements in drinking-water quality through household water treatment, such as chlorination at point of use, can lead to a reduction of diarrhoea episodes by between 35% and 39% (WHO, 2004). Household water treatment and safe storage (HWTS) interventions can lead to dramatic improvements in drinking water quality and reductions in diarrhoeal disease. This positive impact can make an immediate difference to the lives of those who rely on water from polluted rivers, lakes and, in some cases, unsafe wells or piped water supplies. Sobsey (2002) reported that simple methods of water treatment and storage in the home will improve the microbial quality of water and reduce household waterborne diseases.

Many uses of water occur largely at the household (for instance drinking, eating and hand washing), while others may occur away from the home (laundry and bathing). The requirements for domestic supply constitute a very minor component of total water withdrawals (Gleick, 1993; 1996). In the study on water use patterns in East Africa, White *et al.* (1972) suggested that three types of water use exists, which could be defined in relation to normal domestic supply: consumption (drinking and cooking); hygiene (including basic needs for personal and domestic cleanliness) and amenity use (for instance car washing, lawn watering).

2.17 Sanitary Inspection

Sanitary inspection checklist is a form that assesses the likelihood of occurrence of contamination at the springs (Howard, 2002). The data obtained from the inspection aids the conclusion drawn about the on-going status of the springs, as well as the potential risks of contamination in the longer-term. From the data obtained, the major risks which may lead to contamination are identified, so that the required interventions may be carried out.

Sanitary inspection and water quality testing are complementary activities, such that the findings of each assists the interpretation of the other (WHO, 2006). Sanitary inspection provides information that supports effective decision making, at places where quality analysis cannot be performed. Combined with bacteriological, physical and chemical testing, water sources can be assessed and the possible risks from contamination are identified, thus, providing a basis for monitoring. Sanitary inspection allows the risks to be quantified.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Description of study area

The study area is located in Ibadan, the capital of Oyo state. From the 2006 population census, it was reported that Oyo State had a population of 5,591,589 (National Bureau of Statistics, 2006). Ibadan city, which is located in the south west of Nigeria with co-ordinates of 70 23′ 0″N, 30 56′ 0″E has been reported to be the largest city in West Africa. It is 150 kilometers west-east of Lagos and 345 kilometers south –west of the Federal capital territory. This city which was founded in the year 1820 as a war camp has changed into a big city with an average radius of 30 kilometers (SIP, 2004).

The population of Ibadan metropolis has increased rapidly from 627,000 in 1963 to over 3 million in 2004 with over 3,000 villages (SIP, 2004). Ibadan has been the headquarters of the state government since the pre-colonial era. At present, the city has eleven (11) Local Government Areas (LGAs): with five (5) LGAs belonging to the city centre, while the remaining six (6) belong to the peri-urban communities. Figure 3.1 illustrates the map of Ibadan showing the 11 LGAs with the study areas.

3.2 Sampling areas

Most of the springs in this study are located in unplanned residential areas. Some of the populace living in and around where these springs are located are civil servants, while some engage in small-scale businesses, and most of the women are housewives. Most of the people found at the spring sites were women and children.

Ibadan has about twenty-four (24) natural springs, which can supply clean water to the communities where they are located (Table 3.1). Of these 24 natural springs, only seven have been rehabilitated/protected and developed in accordance with the SCP/EPM project viz: Agbadagbudu, Sango, Akeu, Onipasan, Adebayi, Yemoja-Olodo and Moga natural springs.

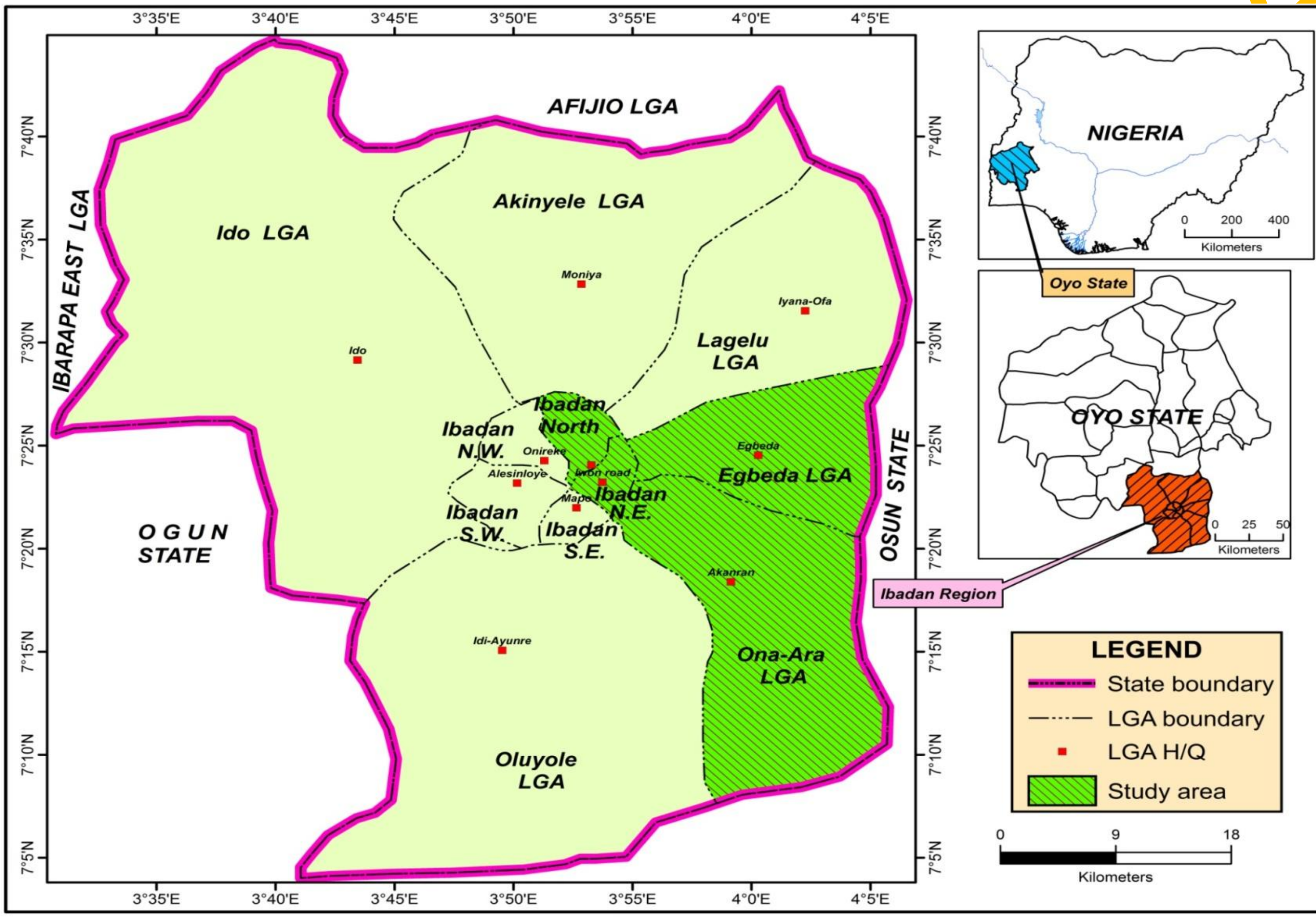


Fig 3.1: Map of Ibadan showing Study Areas

3.3 Study Design

The design of the study is cross-sectional (Descriptive and laboratory based).

3.4 Study Population

The study population comprises of community members who use the spring in the four Local Government Areas.

3.5 Sample Size Calculation

The sample size was calculated using the formula,

$$n = \frac{Z\alpha^2 pq}{d^2}$$ (Kirkwood and Sterne, 2003)

n = desired sample size

Zα = standard normal deviate (1.96) corresponding to 95% confidence interval

p = prevalence of community users of 50% that use spring water as a source of water (Eromosele, 2006).

q = (1 - p) = 1- 0.5

d = precision (0.05)

$$n = \frac{(1.96)^2 \times 0.5 \times (1 - 0.5)}{(0.05)^2} = 384.16$$

The calculated sample size (384.16) was approximated to 400 to make-up for non-responses.

The household sample size was 400

Table 3.1: Profile of Natural springs in Ibadan City

S/N	Name of Spring	Location	Local Govt. Area
1	*Akeu/Osun	Oke-Offa/Babasale	Ibadan North-East
2	*Agbadagbudu	Yemetu/ near Adeoyo hospital	Ibadan North
3	Rogan	Opposite UCH	Ibadan North
4	*Onipasan	Near Oluyoro hospital	Ibadan North-East
5	Tayapon	OkeAremo	Ibadan North
6	Ologbojo	Agugu/Oremeji	Ibadan North-East
7	Alagbafo	Total garden	Ibadan North
8	OdoIye	Beyond IP school	Ibadan North
9	Alaro	Oke-Bola	Ibadan South-West
10	Oleyo	Oke Dada, Mapo	Ibadan South-East
11	*Adegbayi	Adebayi/Old Ife road	Egbeda
12	Arulogun	Kokoru village	Akinyele
13	OdoBaale	Ojoo	Akinyele
14	Alamuyo	Oyemiran village	Lagelu
15	Omi	Adekola village	Lagelu
16	ElewiOdo	Jonkn area	Lagelu
17	*Sango	Sango	Ibadan North
18	*Yemoja-Olodo	Yemoja	Egbeda
19	*Moga	Moga	Ona-ara
20	Omi	Omi-Adio	Ibadan South-West
21	Ogidi	Yejide road	Ibadan South-West
22	Oloro	Alugbo village	Ido
23	Thirty-Thirty	Bodija	Ibadan North
24	Oke-Itunu	Alaro	Ibadan North

Source: SIP, 2004

*** Rehabilitated/protected natural springs**

3.5.1 Sample size calculation for each spring site

A proportional allocation of the sample size to the seven (7) rehabilitated springs was made because of the differences in the frequency of users on a daily basis. The ratio of the sample size for each spring to the total sample size was proportional to the number of people using the spring.Table 3.2 shows the frequency of daily users and sample size for each spring.

3.6 Sample Collection

3.6.1 Spring water sample collection

There were two (2) sampling periods involved (dry and rainy season) for the spring sources. The water samples from the spring sources were collected between the hours of 8 – 11 am. Sanitary inspection of the spring sites was carried out at the point and time of collection of water samples to obtain information on the prevailing environmental and sanitary conditions of the sites. Duplicate samples were collected from each spring site for each season. A total of fifty-six (56) water samples were collected from all the spring sites for physico-chemical, heavy metal and bacteriological analysis for the two (2) sampling seasons. The water bottles were previously washed with detergents, rinsed to prevent contamination of the samples by the collecting containers.

3.6.2 Household water sample collection

A simple random sampling technique was employed for the selection of households where water samples were collected. Forty (40) water samples (10% of the sample size) were collected from the household storage containers of the selected households from the different communities where the spring sites were located. A household container inspection checklist for the household water storage containers was used at the point of collection of stored water samples from the households.

Table 3.2: Frequency of Daily Users and Sample Size for Each Spring.

Natural springs	Frequency of daily users	Sample size
Yemoja-Olodo	100	55
Akeu/Osun	250	138
Onipasan	60	33
Moga	200	110
Agbadagbudu	100	55
Adebayi	5	3
Sango	10	6

3.7 Analytical Method

3.7.1 Physico-chemical analysis

The physico-chemical parameters were analysed according to the standard methods for the examination of water and wastewater (APHA, 1989). The physico-chemical parameters determined included:

3.7.1.1 pH

The pH of a solution is the logarithm to the base 10 of the reciprocal of the hydrogen ion concentration. It is one of the most important operational water quality parameters. Values 0-7 are diminishingly acid, while 7-14 is increasingly alkaline and 7 are neutral. The pH of natural water usually lies in the range 6 – 8.5; however, a lower pH value for water is likely to be corrosive.

Procedure

The pH of the water samples were determined by the use of a calibrated Jenway pH meter.The pH meter was calibrated using buffer solutions of pH 4.0 and 7.0 at a temperature of 25^{o}C. 100mls each of the water sample was measured and the pH meter probe was inserted into the water samples. The pH reading was taken.

3.7.1.2 Temperature

Temperature was determined by the use of a thermometer calibrated in ˚C.

Procedure

The temperature was measured by the use of a thermometer. The thermometer was dipped into the each water sample and the reading taken. The thermometer was then immersed into distilled water before a second reading of the water sample was re-taken.

3.7.1.3 Electrical conductivity

The Electrical Conductivity (EC) of water is the concentration of dissolved mineral salts in the water. The proportion of the different types of salt dissolved in the water greatly affects the value. EC provides a rapid and convenient means of estimating the concentration of electrolytes. The result was expressed in micro Siemens (µS/cm).

Procedure

A calibrated conductivity meter was used in the determination of EC. The conductivity meter was calibrated with 0.01mol/l KCI at 25^{o}C. 100mls of each water sample was measured and the conductivity meter probe was dipped into the water samples. The EC reading was taken.

3.7.1.4 Turbidity

Turbidity in drinking water is as a result of presence of particulate matter. It is a measure of suspended solids. Turbidity is an important operational parameter in the description of microbiological quality of water. According to Howard (2002), combination of turbidity with other parameters would give an adequate description of the microbiological quality of water.

Procedure

The turbidity of the water samples were determined by the use of a spectrophotometer at a specified wavelength of 450nm. The turbidity meter was calibrated using distilled water that was poured into a cuvette. The water samples were each poured into the cuvette and inserted into the spectrophotometer. The values of the turbidity values measured and read in Nephelometric Turbidity Units (NTU).

3.7.1.5 Total Dissolved Solids (TDSs)

Water with a TDS value of greater than 500 mg/l is considered unpalatable (WHO, 1993b).

Procedure

The evaporating dish was cleaned and dried. It was heated to redness, cooled in a desiccator and weighed to constant weight. Two hundred and fifty (250) mls of the water sample was filtered and the filtrate was evaporated to dryness in the weighed dish using a steam bath. The dish was removed from the steam bath, the outside wiped and the residue dried for one hour at 180˚C. The dish was transferred to the desiccator, cooled and weighed. It was then returned to the oven for a further 10 minutes, transferred to the desiccators, cooled and weighed again. This process was repeated until the weight of the dish plus solid was constant. The final weight was then taken. The resultant weight was noted by deducting the weight of the dry dish from the initial weight. This value represents the total dissolved solid. The process was repeated and a second result obtained.

3.7.1.6 Total solids

A total solid is the combination of total dissolved solids and total suspended solids.

Procedure

The evaporating dish was ignited, partially cooled and placed in a desiccator to cool to room temperature and weighed. Two hundred and fifty (250) mls of the water sample was measured into the evaporating dish, evaporated to dryness on a steam bath and further dried at a temperature of 105˚C for 1-2 hours in an oven. It was then cooled in a desiccator and weighed. It was further heated for 15 minutes and cooled. The process was repeated and a second result was obtained.

3.7.1.7 Total hardness

Hardness of water is caused by the presence of calcium and/or magnesium salts.

Procedure

100mls of the water sample was measured into a conical flask and placed on a white paper. 1 ml of the already prepared buffer solution (16.9g NH_4CL, 143ml NH_4OH and 1.25g Mg EDTA diluted to 250ml with distilled water) was added for each 50mls of the water sample and then mixed thoroughly. Two (2) drops of the indicator solution (solution of 0.5g of Eriochrome Black T, 75ml triethanolamine and 25ml alcohol) was added to the mixture. In the presence of calcium and magnesium ions, the solution turns wine-red. The solution was immediately titrated against the standard EDTA solution with continuous stirring. A colour change of wine-red to blue was observed. The process was repeated and a second titre result was obtained.

The result was expressed as mg/l $CaCO_3$. The total hardness was calculated using the formula:

$$\text{Total hardness as mg } CaCO_3/L = \frac{A \times B \times 1000}{\text{Volume of sample (ml)}}$$

Where A = titration of sample (ml)

B = $CaCO_3$ equivalent to 1ml EDTA titrant (mg)

3.7.1.8 Alkalinity

Alkalinity is a measure of the capacity of water to neutralize acid. It measures the ability of a solution to neutralize acids to the equivalence point of bicarbonate or carbonate ions.

Determination of total alkalinity is by measuring the amount of acid needed to bring the sample to a pH of 4.2. At this pH, all the alkaline compounds in the sample are used up. The principle of the determination of total alkalinity is by titration of the sample to the endpoint of a suitable indicator (phenolphthalein). Alkalinity is expressed in terms of calcium carbonate.

Procedure

100mls of the water sample was measured into a conical flask and placed on a white paper. Two (2) drops of phenolphthalein indicator was added to the conical flask and mixed, giving a pink colour. The sample was titrated against a 0.02N standard H_2SO_4 until the pink colour was discharged. The titration was repeated and a second reading taken.

$$\text{Alkalinity as mg/l } CaCO_3 = \frac{B \times N \times 50{,}000}{\text{Volume of sample (ml)}}$$

Where B- total volume (ml) titration of sample
N- Normality of acid.

3.7.1.9 Sulphate (SO_4^{2-})

The method of determination of sulphate is known as the gravimetric method. Sulphate is precipitated in a hydrochloric acid solution as barium sulphate by the addition of barium chloride. There is a direct proportionality between the solid that comes out and that in solution.

Procedure

Two hundred and fifty (250) mls of the water sample was used. The pH of the sample was adjusted with HCL to 5, by using a pH meter. Two (2) mls of HCL was added. The solution was heated to boil, and warm $BaCl_2$ solution was slowly added while stirring gently, until precipitation appears to be complete, then two mls in excess was added. The precipitate was digested at 80^oC overnight. A small amount of ashless filter paper pulp was mixed with the $BaSO_4$. The mixture was transferred to a filter and filtered at room temperature. The function of the pulp was to aid filtration and reduce the tendency of the precipitate to creep. The precipitate was then washed with small portions of warm distilled water until free of Cl^- as indicated by testing with $AgNO_3.HNO_3$ reagent. The filter and precipitate was placed in a weighed crucible and ignited at 800 ^oC for 1hour.

Calculation

$$mg\ SO_4^{2-}/L = \frac{mg\ BaSO_4 \times 411.6}{mL\ sample}$$

Where 411.6 is a constant

3.7.1.10 Phosphate

Phosphorous occurs in natural and wastewaters almost solely as phosphates. Phosphates classified into orthophosphates and organically bound phosphates.

In a dilute orthophosphate solution, ammonium molybdate reacts under acidic conditions to form a heteropolyacid, molybdophosphoric acid. In the presence of vanadium, yellow vanadomolybdophosphoric acid is formed. The intensity of the yellow colour is proportional to the phosphate concentration.

Procedure

The pH of the water sample was tested, to make sure it was not more than 10. Thirty-five (35) mls of the water sample was measured into a 50ml volumetric flask. Ten (10) ml vanadate-molybdate reagent was added and the mixture was diluted to the mark with distilled water. A blank was prepared in which 35ml of distilled water was substituted for the water sample. After 10 minutes, the absorbance of the sample versus the blank was measured with a spectrophotometer at a wavelength of 470nm. The calibration graph was used to take the reading.

Calculation

$$\text{Mg } PO_4^{3-}/L = \frac{\text{mg } PO_4^{3-} \text{ (in 50ml final volume)} \times 1000}{\text{mL sample}}$$

3.7.1.11 Nitrate

In the determination of nitrate, 2,4-xylenol was used. Nitrate reacts with 2,4-xylenol under strongly acidic conditions to produce nitroxylenol . After the formation, nitroxylenol was separated from the solution into sodium hydroxide solution by extraction into solvent and re-extraction into sodium hydroxide solution.

Procedure

The colorimeter was used in the determination of nitrate. 5mls of the water sample was measured into a 100ml conical flask. A blank determination of the reagents was also carried out in a conical flask by excluding the water sample. Two mls of mercuric sulphate solution and 0.5ml of sulphamic acid solution were added to both flasks, mixed and allowed to stand for 5 minutes. One ml of 2,4-xylenol solution was also added to the flasks and mixed. Fifteen mls of sulphuric acid was added slowly to both flasks, mixed and cooled by continuous swirling of the flask under a running cold water tap. It was cooled to 20˚C and allowed to stand for 30 minutes at room temperature.

The contents of the flask were transferred into a 250ml separating funnel by using two (2) successive volumes of about 40ml water for rinsing. Ten mls of toluene was added, shook gently for three minutes and allowed to separate. The lower aqueous layer was run-off to waste, while the separating funnel and contents were washed with 10ml water and the aqueous layer was run-off again to waste. Six mls of water and four mls of 100g/l sodium hydroxide were added to the toluene extract in the separating funnel. The mixture was shaken and allowed to stand for 15 minutes. The lower sodium hydroxide layer was run-off. The absorbance of both test and blank was measured with a colorimeter at a wavelength of 220 nm. From the calibration graph the number of micrograms of nitrate was read. The result was expressed as mg/l.

3.7.1.12 Calcium

In the determination of calcium, EDTA was used. When it was added to water sample containing both calcium and magnesium ions, it combines first with calcium. Calcium can be directly determined with EDTA in the presence of ethanol if the pH of the solution is made sufficiently high (about 12 to13) and if an indicator that combines with calcium only was used.

Procedure

The method used was titrimetric method. Fifty (50) mls of the water sample was measured into a conical flask and hydrochloric acid was added to neutralize the alkalinity, using litmus paper as an indicator. Two (2) mls excess of the hydrochloric acid was added, boiled for about 3 minutes and allowed to cool at room temperature. To the solution, 2mls of sodium hydroxide (NaOH) was added and mixed. The solution was placed on a white paper and 3.5mls of the indicator (murexide) was added and then stirred. Against this solution EDTA was titrated until the colour of the solution was changed from orange-red to lemon-yellow.

The result is expressed as mg/l and calculated as thus:

$$\text{Calcium as } CaCO_3 = \frac{A \times B \times 1000}{\text{Volume of sample (ml)}}$$

Where A = titrant for sample (ml)
B = $CaCO_3$ equivalent to 1ml EDTA titrant

3.7.1.13 Analysis of Heavy Metals

The procedure for determination of heavy metals is similar using the Atomic Absorption Spectrophotometer (AAS), but differs in their standard solutions, lamp and wavelength. Table 3.3 stipulates the standard solutions, wavelengths and flame gases for the various heavy metals. The instruction of the manufacturer was strictly followed. A hollow-cathode lamp for the desired metal was installed and the wavelength for the metal of interest was set. The instrument was turned on and the current suggested by the manufacturer applied to the hollow-cathode lamp. The instrument was allowed to warm up until the energy source stabilizes. A standard solution specific for each metal was aspirated and the aspiration rate of the nebulizer adjusted. The standard was atomized and the absorbance recorded. The water samples were aspirated for each metal in turn into the flame and their absorbances were recorded. The heavy metals were expressed as mg/l. The heavy metals that were analysed were iron, lead, manganese and zinc.

Table 3.3: Standard Solutions, Wavelengths and Flame Gases for the Various Heavy Metals

Metals	Standard solutions	Wavelengths (nm)	Flame gases
Iron (Fe)	Dissolve 1g iron wire in 50ml of 1+1 HNO_3 and dilute to 1000ml with water; 1ml=1mgFe	248.3	Air-acetylene
Lead (Pb)	Dissolve 1.598g lead nitrate, in about 200ml water, add 1.5ml conc. HNO_3 and dilute to 1000ml with water;1ml=1mgPb	283.3	Air-acetylene
Manganese (Mn)	Dissolve 3.076g manganous sulphate in about 200ml water, add 1.5ml conc. HNO_3 and dilute to 1000ml with water; 1ml = 1mg Mn	279.5	Air-acetylene
Zinc (Zn)	Dissolve 1g zinc metal in 20ml 1+1 HCl and dilute to 1000ml with water; 1ml = 1mg Zn	213.9	Air-acetylene

Source: APHA, 1989

3.7.2 Bacteriological analysis

Two (2) methods were used for the bacteriological analysis: pour plate and the multiple tube fermentation technique.

3.7.2.1 Multiple tube fermentation technique

The multiple tube technique is used in estimating the number of coliform bacteria in water, sewage, milk and milk products (APHA, 1989).

Three (3) 10ml, three (3) 1ml and three (3) 0.1ml volumes of the water sample were added to MacConkey broth in MacCartney bottles containing inverted Durham tubes to indicate production of gas. In this technique varying volumes of the water sample were examined in order to obtain a mean result. The Most Probable Number (MPN) of the coliforms in 100ml was computed on the basis of the various combinations of positive and negative results.

Procedure

Ten mls of the double strength, one ml and 0.1ml, both of the single strength of the MacConkey broth was dispensed into screw capped bottles of appropriate sizes, with each bottle containing a sterilized inverted Durham tube to collect gas. Using sterile pipettes, the water samples were inoculated into the medium as follows: Three (3) 10ml of the water sample to 10ml double strength; Three (3) 1ml of the water sample to 5ml single strength and three (3) 0.1ml water sample to 5ml single strength. The bottles were incubated at 37 ^{o}C and examined after 24 hours observed for growth, acid and gas production. The bottles that showed positive results (presence of bubbles and colour change from purple to yellow) were tabulated and the MPN obtained from the McGrady statistical table.

3.7.2.2 Pour plate method

This method refers to the measurement of the population of living organisms in a sample by culture. The water samples were diluted serially. The serial dilution enabled discrete rather than merged colonies to be formed, thus, facilitating colony count.

Procedure

One ml of each water sample and subsequent diluents (10^{-1}) was measured into sterile Petri-dishes by the aid of a pipette. Ten ml of the molten nutrient agar, MacConkey agar and pseudomonas agar (cooled to 45^{o}C) were poured on the samples; one (1) medium for each Petri-dish. The dishes containing the medium and the innoculum were swirled gently. After solidification, the dishes were inverted and incubated at 37^{o}C for 24 hours. The total bacterial count were done by counting the different colonies on the agar plates after the incubation and multiplying by the inverse of the dilution factor (10^{3}) to obtain the viable counts per ml of the original sample. The different colonies were picked from the dishes and streaked on corresponding fresh agar plates to obtain the pure cultures. They were gram stained and observed under the microscope.

Gram staining process

A smear of the organism was made on a slide by using a wire loop. It was emulsified into sterile water and allowed to dry. Crystal violet was used as a stain for 60 seconds and the solution poured off (primary staining). It was then rinsed with water and the mordant, lugols iodine was added for 60 seconds, thus, allowing the fixing of the stain on the cells for visibility under the microscope. It was rinsed with water, decolourized with ethanol for 30 seconds and rinsed again immediately with water. It was counter stained with safarinin for 60 seconds, rinsed with water and allowed to dry. The slide was then observed under the microscope.

Media

The following media were used

1. Nutrient agar: This serves as the basic microbiological medium. It consists of nutrient broth to which 1.5% agar was added.

2. MacConkey agar: This is a medium based on MacConkey's broth but with neutral red as indicator. It is the selective and differential medium for coliforms (members of *Enterobacteriaceae*).

3. Pseudomonas agar: This is a selective and differential medium for pseudomonas.

3.8 Methods of Data Collection

Qualitative and quantitative data on the associated prevailing environmental and sanitary conditions of the springs and household water storage containers were collected. Information on socio-demographic characteristics as well as knowledge on effective spring utilization and health status was also collected using different instrument.

3.8.1 Focus group discussion

The Focus Group Discussion (FGD) affords one the opportunity to interact with some of the community members, to obtain information that guided structuring of the questionnaire. For each of the seven (7) areas where the selected springs were located, two FGDs with participants numbering between three and eight were conducted each for men and women. The FGD was recorded with a recorder and translated. **(**Appendix I show the focus group discussion guide).

3.8.2 Observation

3.8.2.1 Sanitary inspection for springs

Sanitary Inspection (SI) was carried out at the spring sites during the period of sampling (dry and rainy seasons). The SI forms contained questions framed for a yes or no answer, thus indicating the possibility of the presence of a risk factor. All the yes answers were ranked 1 and the no answers were ranked 0. The questions with yes answers were summed up, so that the total score of the risks were recorded over all the possible risk factors, in this case, 13.

The risk scores were graded into four (4) categories according to the degree of contamination of the water, in ascending order of the values from no risk to very high risk: no risk (0); low risk (1-3); intermediate to high risk (4-6) and very high risk (7-≥9). (Appendix II shows the sanitary inspection form for springs).

3.8.2.2 Household water storage container inspection

The household container inspection checklist consisted of ten (10) questions. This inspection was carried out at households at the point of collection/drawing water samples from the storage containers. It was carried out for the forty (40) households where the water samples were collected. The questions were also framed for a yes or no answer, indicating the possibility of the presence of a risk factor. All the questions with a yes answer were summed up, so that the total score of the risks were recorded over all the possible risk factors, in this case, 10. The scores were graded into four (4) categories according to the degree of contamination of the water, in ascending order of the values from low to very high: low (0-2); medium (3-5); high (6-8) and very high (9-10). (Appendix III shows the household water storage container inspection checklist guide).

3.8.3 Survey

3.8.3.1 Questionnaire

A pre-tested semi-structured questionnaire with both open-ended and closed questions was used for data collection. A simple random sampling technique was used to select the 400 households used for the study.

There were (three) 3 sections comprising of questions on socio-demographic characteristics, effective utilization and health status. Effective utilization had 3 subsections: optimal, hygienic and consistent uses. The four hundred (400) households were selected for the study. Men and women were the primary respondents. (Appendix IV shows the questionnaire with the different sections).

CHAPTER FOUR

RESULTS

Presented in this chapter are the findings of the study: the results of observation on the environmental conditions and sanitary status of springs; the results of the physico-chemical and bacteriological analysis of the springs for rainy and dry seasons as well as the findings of the bacteriological analysis for the water samples collected from the household water storage containers. The results of the sanitary inspection of the springs and household water storage containers as well as information from the focus group discussion and the knowledge of community users on effective spring utilisation were also presented in this chapter. The results are presented in figures, charts and tables showing frequencies, percentages, mean and standard deviation. Inferential statistics(ANOVA, t-test and correlation co-efficient) were used to determine statistical significant differences at $p \leq 0.05$ of some of the variables.

4.1 Sanitary and Environmental Conditions.

4.1.1 Springs in Ibadan North Local Government Area

4.1.1.1 Agbadagbudu Natural Spring

The spring is located in Agbadagbudu community in the Yemetu-Adeoyo area of Ibadan North Local Government Area, about 900m from Mapo Hill. The Agbadagbudu natural spring water project came into being in 2004, as a demonstration project. The locality where the spring is situated is densely populated and the topography is naturally hilly. The spring is protected by a gated wire mesh which was converted to a block wall. The technology of collecting water is through the use of hand pumps fitted to a reservoir. There are six hand pumps, hence, enabling six persons to draw water from the reservoir at the same time. It serves as a major source of water for a large number of users from the immediate and adjoining communities, with a daily estimate of 100 persons during the rainy season to 400 persons during the dry season for the 8-hour period it is opened for use. Plate 4.1 shows Agbadagbudu natural spring after the protection.

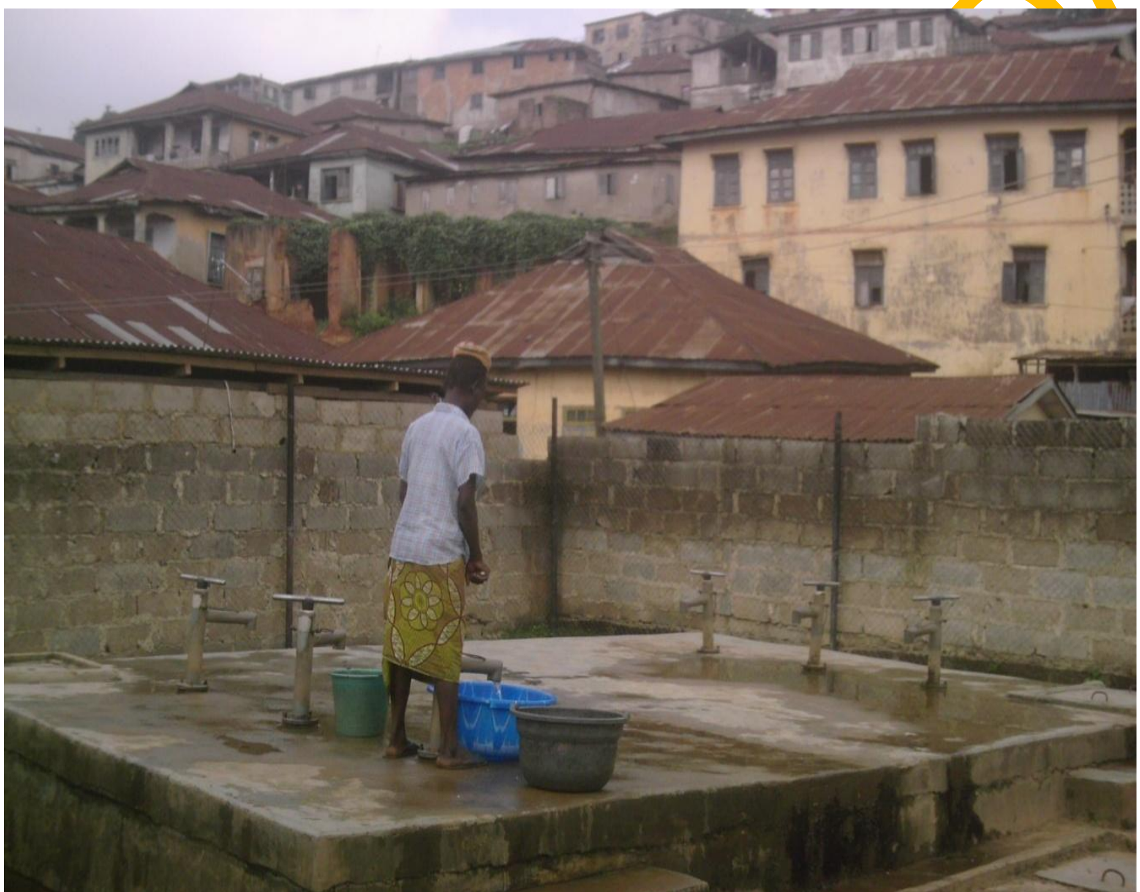


Plate 4.1: The Agbadagbudu natural spring located in Yemetu, showing the six hand pumps.

4.1.1.2 Sango (Odo Baba Dada) Natural Spring

The name of this spring originated from the name of the man that discovered it, Baba Dada (Dada's father). The male spring user discussants stated that they do not know how old the spring was, but they believe it is up to 30 years, and the man whom the spring was named after said it has healing powers. Similarly, the women said they all met the spring there. It is located in Sango Isopako area of Oke-Itunu in Ibadan. The spring is located in a hilly and rocky terrain. The environmental and sanitary condition surrounding this spring is very poor. There is an expanse of land uphill of the spring used for dumping refuse and wood shavings from the nearby carpentry workshops. Faeces from man and animal could be found very close to the spring. Houses with faulty solid waste disposal close to the spring were observed. Human activities around this spring can produce leacheates that may compromise the quality of the spring. Plates 4.2 and 4.3 show the spring and the surrounding environment

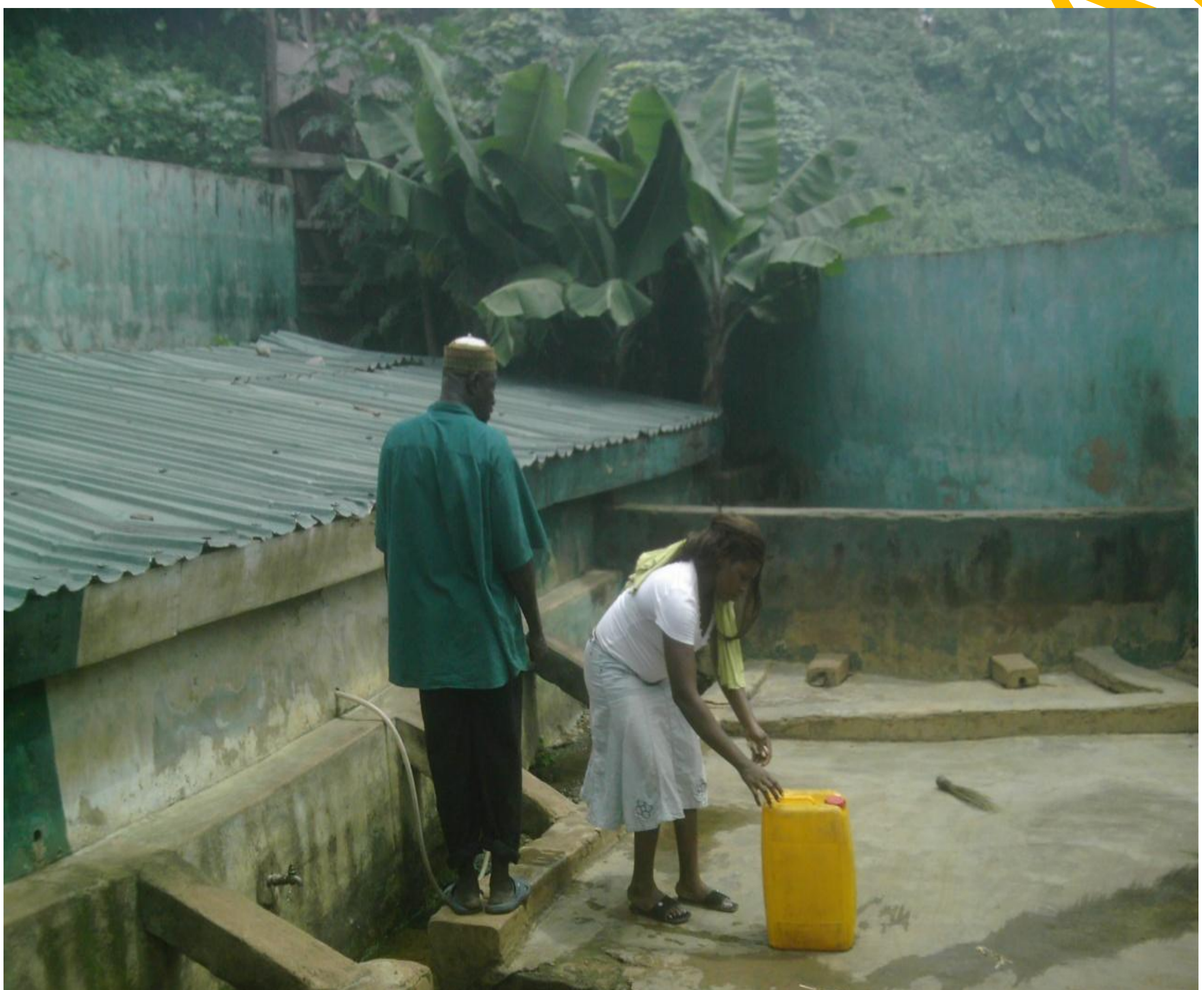


Plate 4.2: Sango natural spring located at Sango Isopako, showing the reservoir with the taps

Plate 4.3: The surrounding environment of Sango spring which is used as refuse dump.

4.1.2 Springs in Ibadan North East Local Government Area

4.1.2.1 Odo-Akeu (Odo Osun) Natural Spring.

The Odo-Akeu natural spring is also known as Odo-Osun. It is locataed in Oke-Offa Babasale area of Ibadan North East Local Governmnet Area (LGA). The length of time the spring has been in existence is unknown as many discussants stated during the FGD that they all met the spring and so did their parents and older relatives.This was the first natural spring that was rehabilitated in 1996 by the combined efforts of the community, LGA, UNICEF and the Sustainable Ibadan Project (SIP). The topography of the area is rocky and hilly. The prevailing environmental and sanitary conditions of the spring was poor. There was a pool of coloured water formed outside the fenced spring, from where people draw water for domestic chores. The spring eye is located in a residential area of a community member. The immediate surrounding of the spring eye was overgrown by weed and faeces of both man and animal could be seen not far from it. Domestic animals had access to this spring eye, and the residents where this spring eye was located fetch water directly from it and sometimes allow people to fetch water from there during hours the spring was not open to the public. Plates 4.4 and 4.5 show the women carrying water from the spring and the pool of water outside of the spring respectively.

Plate 4.4: Women carrying water from Akeu spring

Plate 4.5: The surrounding of Odo-Akeu spring showing stagnant water which seeps into the spring water.

4.1.2.2 ONIPASAN NATURAL SPRING

The Onipasan natural spring project was completed in 2004. It is located near the Oluyoro Catholic hospital, Oluyoro area of Ibadan. The adopted design technology was simply a replication of the Odo-Akeu and Agbadagbudu natural springs. The source was protected with concrete wall and a wire mesh was used as a covering. This source was fenced off and secured with an iron gate, preventing people from gaining access. An underground tank is connected to the source, to which six outlet taps are fixed for water collection. This area had two entry and exit gates. The spring was located very close to the road. The immediate environment of the spring was good, but the surrounding environment was poor, as observed by the presence of faeces and close proximity of a mechanic workshop. Plates 4.6 and 4.7 show the spring and the surrounding environment.

Plate 4.6: A child fetching water from the reservoir of Onipasan spring; and a faulty tap.

Plate 4.7: A woman washing clothes around Onipasan spring environs, thus soap filters and enters the spring water.

4.1.3 Springs in Egbeda Local government

4.1.3.1 Yemoja-Olodo Spring

The spring is located along the road from Monatan to Iwo in Egbeda local government area. It is believed that the spring has been in existence for a long time because most of the users met the spring there. The area is sparsely populated. The spring is not fenced; hence animals have access to it. It has no time regulation nor is a token collected at the point of collection. The source is protected with concrete slabs and covered with zinc iron. A simple method of water collection is adopted. Taps are used, but the collecting area is usually over flooded because the taps were always in a state of disrepair. The environmental condition of the spring was poor. The surrounding of the spring was overgrown by grass. A rail line is located upstream of the spring. Plate4.8 shows the collection area over flooded with water.

Plate 4.8: Water logged area where water is fetched from at Yemoja-Olodo spring.

4.1.3.2 Adegbayi Natural Spring

Adegbayi natural spring is located along the New Ife road. The Adegbayi natural spring project was completed in 2004 as a replicate of the Agbadagbudu spring. Adegbayi is a low density residential area. The spring source was protected with a concrete ring, and then connected to an underground water reservoir to which four hand pumps were fixed for water collection. The spring site was fenced with an iron mesh with an iron gate fixed to it. The floor of the site was cemented, but with an open drain. A token of N5 is collected for a basin, an equivalent of 25 litre gallon. The environmental and sanitary condition of the spring was poor as observed by the presence of a mechanic workshop and pool of water beside the spring, which was overgrown by grass. Plates 4.9 and 4.10 show Adegbayi spring and the surroundings.

Plate 4.9: Adegbayi spring showing people fetching water and the 4 hand pumps

Plate 4.10: The surroundings of Adegbayi spring showing stagnant water.

4.1.4 Springs in Ona-ara Local Government Area

4.1.4.1 Moga Natural Spring

The Moga natural spring rehabilitation project was completed in 2002. It was among the three natural springs used as a demonstration project from which replicates were made. The spring is located in Moga along Olunloyo and Amuloko area of Ona-ara LGA. The spring is believed to have some spiritual inclinations as it is located on rocks used as an ori-oke (prayer ground). The terrain where this spring is located is rocky and hilly. The sanitary condition of the spring was poor, as observed by the presence of a flowing river just upstream of the spring and the difficulty of disposal of liquid waste because of the rocky terrain. The pipes connected from the source to the water reservoir had been vandalized, thus, water was then fetched directly from the source. The spring serves as the only source of water for those living around it, because of the difficulty of digging wells. Plates 4.11and 4.12 show the spring source and vandalized pipes.

PLATE 4.11: The water source of Moga spring where people fetch water directly.

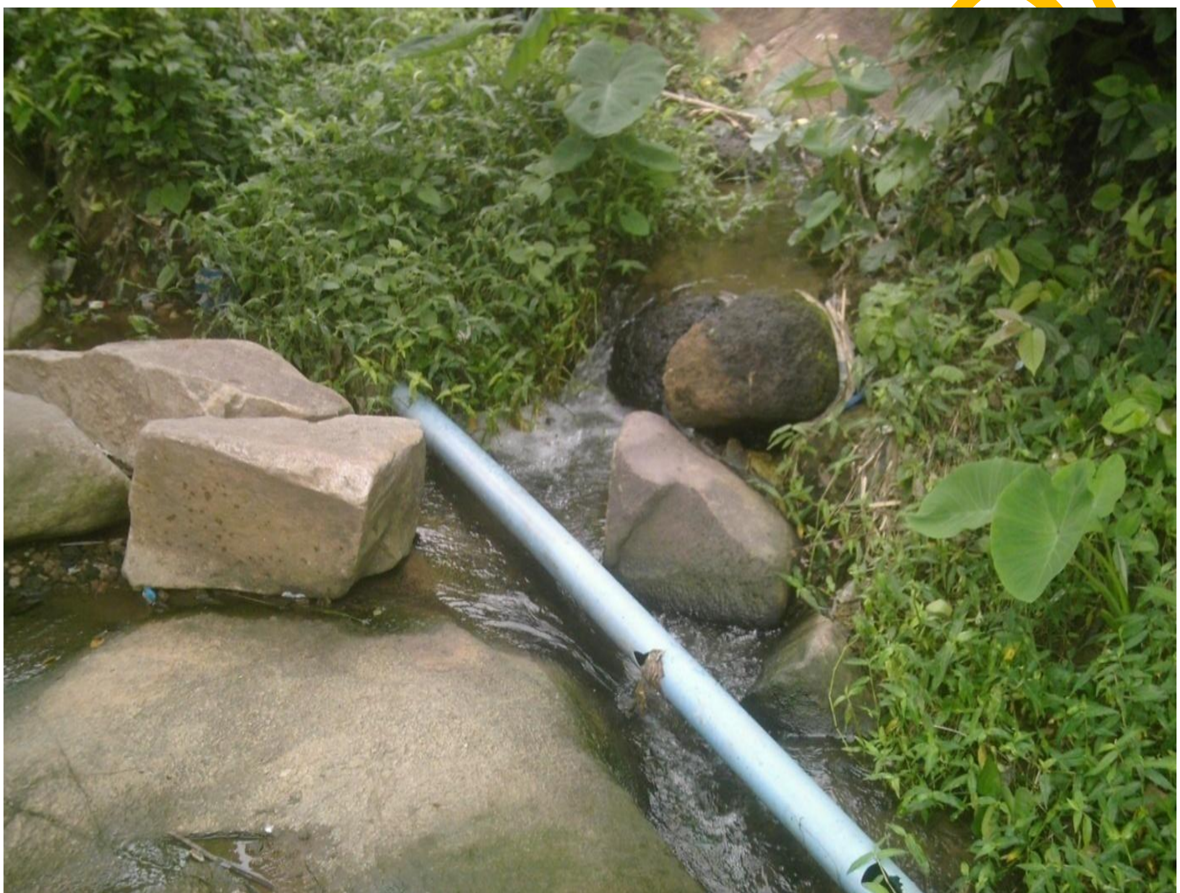


Plate 4.12: Vandalized pipes that carry water from the source to the reservoir

4.2Physico-Chemical Parameters of Springs during Dry and Rainy Seasons.

Table 4.1 shows the physico-chemical parameters during the dry season in comparison to the WHO limits. The mean values for the physico-chemical parameters were within the acceptable values stipulated by WHO guidelines. However, the mean values for phosphate for all the springs were above the limit of 0.03mg/l.

Similarly, during the rainy seasons all parameters except electrical conductivity and phosphate had mean values within the acceptable limit. The mean values for electrical conductivity of 3 springs: Agbadagbudu, Sango and Odo-Akeu (437.5±4.95, 789±11.3 and 777±1.4) µS/cm respectively were higher than the WHO stipulated guideline of 400 µS/cm. The mean values for phosphate of all the springs during the rainy season were above the acceptable guideline limit. Table 4.2 shows the physico-chemical and heavy metal parameters for the springs during the rainy season.

During the Focus Group Discussion (FGD), the men in these communities stated that the water had no colour, taste nor odour. Similar reports about the water were obtained from the women who also said that the spring water neither darkens the pot nor storage containers. These reports are supported by the values obtained from water analysis for total hardness during both seasons for all the springs. The values obtained for total hardness were less than 100mg/l stipulated by the recommending agencies, thus, the water cannot be regarded as hard water which darkens storage containers and pots.

Table 4.1: Physico-Chemical Parameters for Spring Water Samples during Dry Season

Parameters	Spring Sources							WHO
	Agbadagbudu (Mean ± S.D)	Sango (Mean±S.D)	Odo-Akeu (Mean±S.D)	Onipasin (Mean±S.D)	Yemoja (Mean±S.D)	Adegbayi (Mean±S.D)	Moga (Mean±S.D	
Physical								
Temperature (^{o}C)	29.75±0.07	30.1±2.6	29.8±0.9	30±1.7	29.3±0.6	29.8±1.4	29.8±2.1	-
pH	7.05±0.07	5.1±0.9	6.89±0.1	5.70±0.6	7.2±0.07	6.8±0.8	6.75±0.07	6.5-8.5
Total solids (mgl^{-1})	648.5±2.12	1005±21.2	863.5±10.6	750±7.07	803.5±12	919.5±4.9	799.5±6.4	500-1500
Total dissolved solids (mgl^{-1})	175±7.07	395±7.1	430.0±30.2	190±25.7	275±7.1	330±8.9	195±7.07	500
Electrical conductivity (µS/cm)	105±4.7	175±16.9	182.5±3.5	95±9.4	150±4.8	160±7.1	132.5±3.53	400
Turbidity (NTU)	0.75±0.78	0.25±0.07	0.3±0.3	0.85±0.78	0.3±0.01	0.2±0.04	0.25±0.07	5.0
Chemical (mgl^{-1})								
Total hardness	42.95±0.21	49.05±0.07	65.3±0.4	75.20±0.42	56.2±0.8	58.8±0.2	68±0.28	100
Alkalinity	17.8±0.14	16.95±0.21	26.6±0.4	27.95±0.21	21.4±0.2	22.7±0.2	25.7±0.14	≤120
Calcium	29.1±0.28	25.55±0.49	41.4±1.9	34.30±0.99	33.8±1.8	29.5±0.5	35.85±0.5	75-200
Nitrate	5.6±0.14	7.25±0.07	8.8±0.3	12±0.14	6.95±0.4	9.9±0.1	6.2±0.14	45
Phosphate	3.6±0.3	5.7±0.14	6.1±0.3	6.85±0.07	4.1±0.3	7.3±0.3	3.05±0.07	0.03
Sulphate	5.35±0.21	7.05±0.35	10±0.1	13.60±0.14	8.5±0.3	11.9±0.1	5.55±0.21	200
Heavy Metals (mgl^{-1})								
Iron	0.1±0.01	0.1±0.01	0.1±0.003	0.05±0.002	0.1±0.008	0.005±0.001	0.0±0.006	0.3
Manganese	0.01±0.001	0.01±0.009	ND	ND	ND	ND	ND	0.1
Lead	ND	0.01±0.007	ND	ND	ND	0.01±0.003	ND	0.01
Zinc	ND	ND	ND	ND	ND	ND	ND	5.0

ND- Not Detected

Table 4.2: Physico-Chemical Parameters for Spring Water Samples during Rainy Season

Parameters	Spring Sources							WHO
	Agbadagbudu (Mean ± S.D)	Sango (Mean±S.D)	Odo-Akeu (Mean±S.D)	Onipasin (Mean±S.D)	Yemoja-Olodo (Mean±S.D)	Adegbayi (Mean±S.D)	Moga (Mean±S.D)	
Physical								
Temperature (^{o}C)	29.75±0.07	28.15±0.2	28.2±4.9	28.10±5.2	27.95±9.1	27.95±9.4	27.9±4.6	-
pH	5±1.3	5.45±0.07	6±0.1	5.65±0.07	6.6±3.1	5.7±0.8	6.2±2.1	6.5-8.5
Total solids (mgl^{-1})	802.5±3.54	1055±7.07	912.5±17.7	747.5±3.54	722.5±3.5	677.5±3.5	640±14.1	500-1500
Total dissolved solids (mgl^{-1})	275±7.07	495±7.07	480±14.1	225±7.07	160±14.1	85±7.1	150±11.8	500
Electrical conductivity (µS/cm)	437.5±4.95	789±11.3	777±1.4	347.5±3.54	170.5±6.4	107.5±7.8	180±1.41	400
Turbidity (NTU)	ND	0.5±0.07	ND	ND	7 ±3.1	1±0.02	ND	5.0
Chemical (mgl^{-1})								
Total hardness	46.15±1.2	52±2.5	48±2.7	36.3±1.13	55.3±0.4	65.7±0.2	50.8±0.35	100
Alkalinity	10.45±0.07	12.5±0	15.1±0.1	12.65±0.21	20.3±0.3	25.4±0.6	16.15±0.2	≤120
Calcium	40±0.28	45.25±0.35	39.5±9.4	23.90±1.56	46.4±0.5	51.3±0.4	43.75±0.35	75-200
Nitrate	6.55±0.07	8.1±0.14	9.2±1.2	7.70±0.28	7.5±1.6	8.7±0.1	11.75±0.35	45
Phosphate	3.75±0.35	6.1±0.14	6±2.01	4.90±0.14	3.7±0.1	6.5±0.9	8.1±0.14	0.03
Sulphate	6.05±0.07	6.5±0.9	7.1±0.2	6.50±0.28	5.6±0.3	10.8±0.3	9.35±0.21	200
Heavy Metals (mgl^{-1})								
Iron	0.1±0.01	0.2±0.1	0.2±0.09	0.1±0.05	0.3±0.09	0.1±0.06	0.1±0.04	0.3
Manganese	ND	0.02±0.01	ND	0.01±0.01	0.01±0.01	ND	ND	0.1
Lead	ND	0.01±0.004	ND	0.01±0.008	0.01±0.01	ND	ND	0.01
Zinc	ND	ND	ND	ND	ND	ND	ND	5.0

ND- Not Detected

4.3 Bacteriological Quality of Water Samples

4.3.1 Bacteriological Quality of Water Samples from Springs during The Rainy And Dry Seasons

The bacteriological parameters analysed were Total aerobic plate count (TAPC), Total coliform count (TCC), *E.coli* count and *Pseudomonas aeruoginosa*count (PAC).

Table 4.3 shows the bacteriological quality of springs duringthe dry season. The mean TCC during the dry season had a range of (1.15 x 10^3±70.7 - 11x 10^3±356.21) MPN/100mlobtained from Agbadagbudu and Yemojasprings respectively. During the dry season, the bacteriological analysis for Agbadagbudu and Moga springs showed absence of*E.coli*, hence there was no faecal contamination.

During the rainy season, the mean TCC had a range of (0.75x 10^3±70.7 – 4.45x 10^3±70.7) MPN/100ml, which was obtained from Agbadagbudu and Adegbayi natural springs respectively. All springs showed contamination with *E.coli* as their mean values were above the WHO recommended limit of 0MPN/100ml. The highest mean *E.coli* counts (1.8x 10^3±165.4, 1.8x 10^3±28.9 and 1.8x 10^3±29.6) MPN/100ml obtained during the rainy season were from Sango, Yemoja and Adegbayi natural springs respectively. Agbadagbudu and Onipasan had the least mean *E.coli* count (0.02x 10^3±2.4 and 0.02x 10^3±1.5) MPN/100ml during the rainy season respectively (Table 4.4).

The mean TCC of all springs for both seasons exceeded the WHO limit of 10MPN/100ml. Albeit above the WHO recommended limit, the least mean value for TCC was obtained in Agbadagbudu natural spring (0.75x 10^3±70.7 and 1.15x 10^3±70.7) MPN/100ml during the rainy and dry seasons respectively. Figure 4.1 shows the mean TCC of all springs for both seasons.

Table 4.3: Bacteriological Quality of Springs during Dry Season

Communities	Parameters			
	TAPC(cfu/ml) Mean ± s.d	TCC (MPN/100ml) Mean ± s.d	*E.coli* count (MPN/100ml) Mean ± s.d	PAC (cfu/ml) Mean ± s.d
Agbadagbudu	14.5 x 10^3±707.1	1.15 x 10^3±70.7	ND	ND
Sango	10.5 x 10^3±707.1	4.6 x 10^3±565.7	0.35 x 10^3±70.71	ND
Odo-Akeu	9.05 x 10^3±70.7	3.1 x 10^3±141.4	0.5 x 10^3±141.4	ND
Onipasan	12 x 10^3±1414.2	9 x 10^3±52.91	1 x 10^3±282.84	3.5 x 10^3±707.11
Yemoja	2.5 x 10^3±721.1	11 x 10^3±356.21	0.7 x 10^3±141.4	ND
Adegbayi	23.5 x 10^3±707.1	10.5 x 10^3±707.1	0.6 x 10^3±23.2	2 x 10^3±72.82
Moga	7.55 x 10^3±777.8	3.9 x 10^3±424.26	ND	ND
WHO	-	10	0	-

ND- NOT DETECTED

Table 4.4: Bacteriological Quality of Springs during Rainy Season

Communities	Parameters			
	TAPC (cfu/ml) Mean ± s.d	TCC (MPN/100ml) Mean ± s.d	*E.coli* count (MPN/100ml) Mean ± s.d	PAC (cfu/ml) Mean ± s.d
Agbadagbudu	$10 \times 10^3 \pm 134.7$	$0.75 \times 10^3 \pm 70.7$	$0.02 \times 10^3 \pm 2.4$	$18 \times 10^3 \pm 127.9$
Sango	$23 \times 10^3 \pm 189.9$	$2.1 \times 10^3 \pm 141.4$	$1.8 \times 10^3 \pm 165.4$	$0.011 \times 10^3 \pm 0.71$
Odo-Akeu	$5.15 \times 10^3 \pm 70.7$	$2.2 \times 10^3 \pm 141.4$	$0.025 \times 10^3 \pm 7.1$	$0.015 \times 10^3 \pm 7.1$
Onipasan	$16 \times 10^3 \pm 142.8$	$3 \times 10^3 \pm 31.7$	$0.02 \times 10^3 \pm 1.5$	$0.02 \times 10^3 \pm 2.8$
Yemoja	$11 \times 10^3 \pm 1414.2$	$2.1 \times 10^3 \pm 141.4$	$1.8 \times 10^3 \pm 28.9$	$1.25 \times 10^3 \pm 70.7$
Adegbayi	$20.5 \times 10^3 \pm 707.1$	$4.45 \times 10^3 \pm 70.7$	$1.8 \times 10^3 \pm 29.6$	$0.02 \times 10^3 \pm 1.8$
Moga	$18.5 \times 10^3 \pm 707$	$2.35 \times 10^3 \pm 70.7$	$1 \times 10^3 \pm 34.3$	$1 \times 10^3 \pm 17.9$
WHO	-	10	0	-

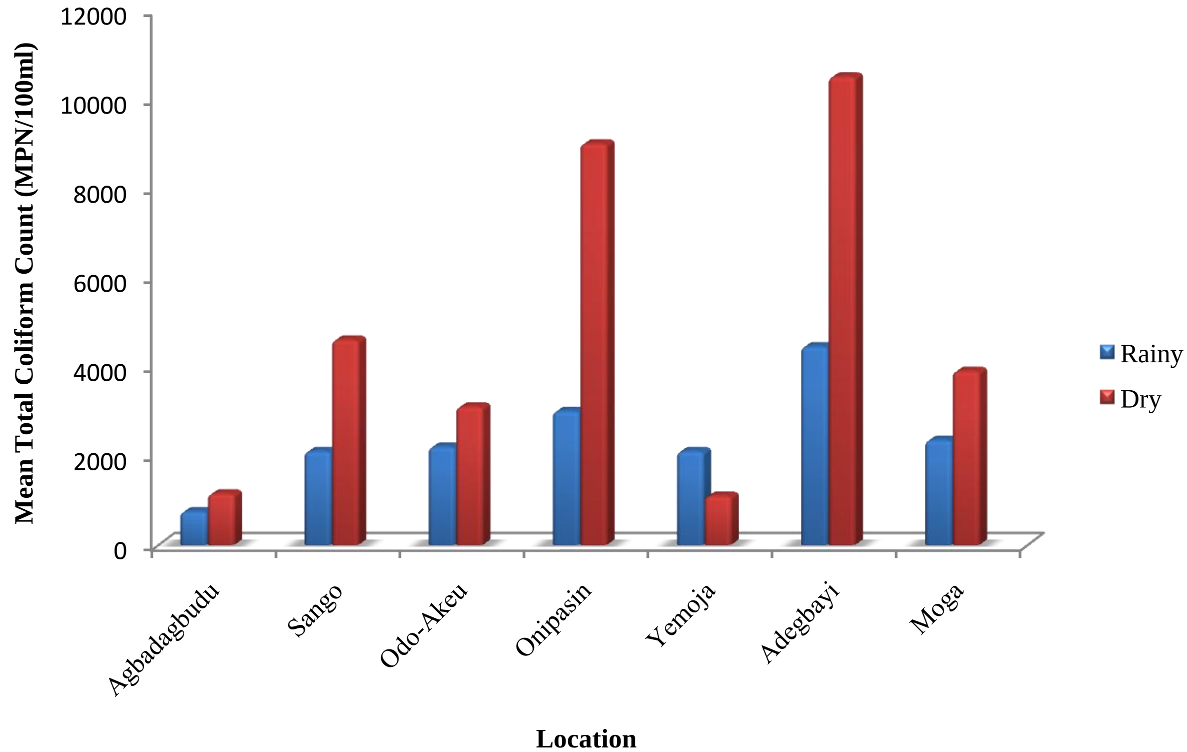


Figure 4.1: Mean total coliform count for natural springs during dry and rainy seasons.

4.3.2 Bacteriological Quality of Water Samples from Springs and Households

Table 4.5 shows the bacteriological quality of water samples for springs and household water storage containers. For all the parameters analysed (TAPC, TCC, *E.coli*, and PAC), the mean values of the samples from the springs were higher than the mean values of the samples from the household water storage containers.

Mean TCC for both springs and household water storage containers were above the WHO recommended limit of 10MPN/100ml. Similarly, the mean *E.coli* count of water samples from both springs and household water storage containers exceeded the WHO recommended limit of 0MPN/100ml. The least mean *E.coli* count ($0.0003 \times 10^3 \pm 0.02$) MPN/100ml was obtained from the water samples from household storage containers in Sango. Figure 4.2 shows the mean *E.coli* count of springs and household water storage containers against the WHO recommended limit.

Table 4.5: Bacteriological Quality of Water Samples from Sources and Households Storage Containers

Communities	PARAMETERS				
	Water samples	TAPC (cfu/ml) Mean ± s.d	TCC (MPN/100ml) Mean ± s.d	*E.coli* count (MPN/100ml) Mean ± s.d	PAC (cfu/ml) Mean ± s.d
Agbadagbudu	Spring	10 x 10^3±134.7	0.75 x 10^3±70.7	0.02 x 10^3±2.4	18 x 10^3±127.9
	Household	1.85 x 10^3±173.21	0.13 x 10^3±36.97	0.001 x 10^3±0.7	ND
Sango	Spring	23 x 10^3±189.9	2.1 x 10^3±141.4	1.8 x 10^3±165.4	0.01 x 10^3±0.71
	Household	1.8 x 10^3±167.33	0.13 x 10^3±29.44	0.0003 x 10^3±0.02	ND
Odo-Akeu	Spring	5.15 x 10^3±70.7	2.2 x 10^3±141.4	0.025 x 10^3±7.1	0.02 x 10^3±7.1
	Household	1.28 x 10^3±271.36	0.3 x 10^3±28.17	0.004 x 10^3±1.76	0.002 x 10^3±0.55
Onipasan	Spring	16 x 10^3±142.8	3 x 10^3±31.7	0.02 x 10^3±1.5	0.02 x 10^3±2.8
	Household	1.17 x 10^3±57.74	0.14 x 10^3±34.64	0.002 x 10^3±0.73	ND
Yemoja-	Spring	11 x 10^3±1414.2	2.1 x 10^3±141.4	1.8 x 10^3±28.9	1.25 x 10^3±70.7
Olodo	Household	1.85x 10^3 ± 173.21	0.13 x 10^3±36.97	0.13 x 10^3±12.1	ND
Adegbayi	Spring	20.5 x 10^3±707.1	4.45 x 10^3±70.7	1.8 x 10^3±29.6	0.02 x 10^3±1.8
	Household	3.03 x 10^3±208.17	0.2 x 10^3±11.55	0.72 x 10^3±35.31	0.02 x 10^3±0.58
Moga	Spring	18.5 x 10^3±707	2.35 x 10^3±70.7	1 x 10^3±34.3	0.1 x 10^3±17.9
	Household	1.03 x 10^3.33 ± 86.6	0.092 x 10^3±21.67	0.02 x 10^3±3.23	0.001 x 10^3±0.52
WHO		-	10	0	-

ND- Not Detected

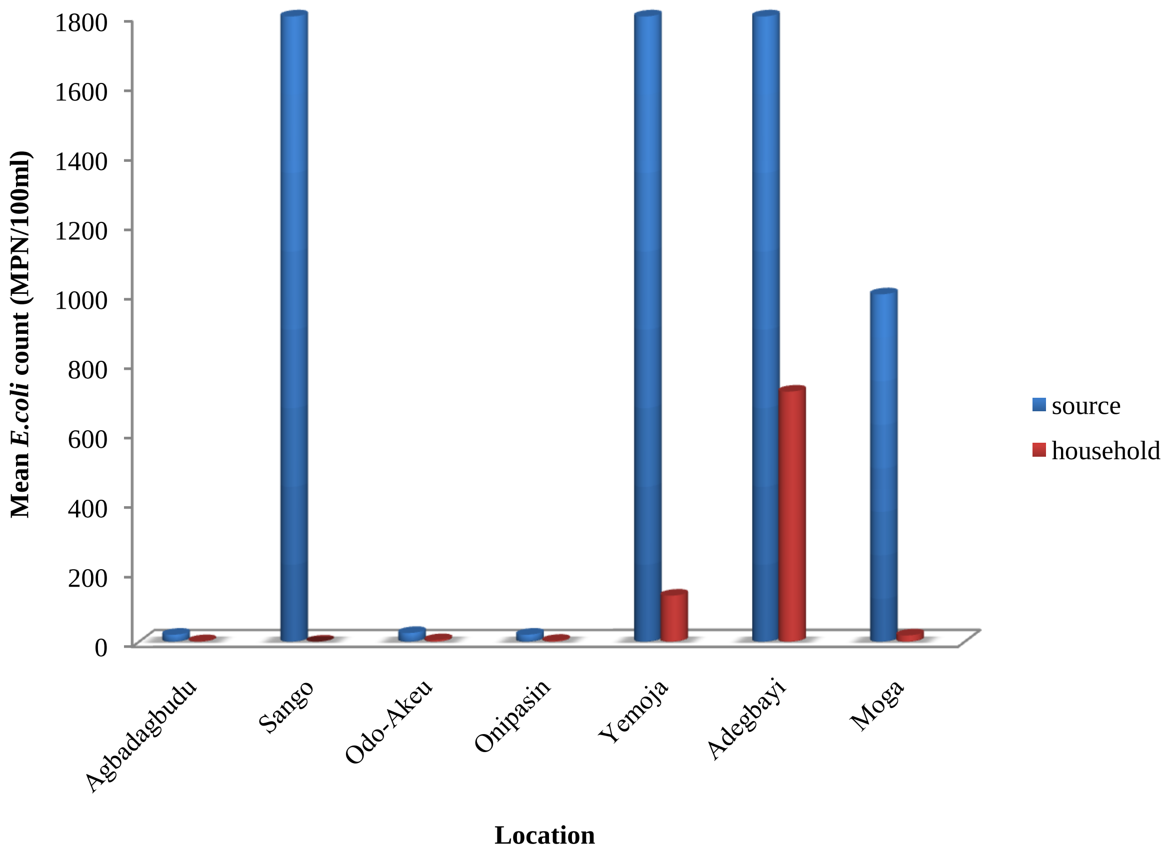


Figure 4.2: Mean *E.coli* count of samples from springs and household water storage containers

4.3.3 Comparative Bacteriological Quality of Water Samples Between Communities

Table 4.6 shows the comparative bacteriological quality of water samples from household storage containers between communities that use the spring. The bacteriological parameters that were analysed and compared were TAPC, TCC, *E.coli* count and PAC.

The mean values of TAPC for Agbadagbudu, Sango, Odo-Akeu, Onipasan, Yemoja, Adegbayi and Moga were statistical significance, F statistics = 51.496, $p<0.05$
The mean values of TCC for Agbadagbudu, Sango, Odo-Akeu, Onipasan, Yemoja, Adegbayi and Moga were statistical significance, F statistics = 3.395, $p<0.05$
The mean values of *E.coli* count for Agbadagbudu, Sango, Odo-Akeu, Onipasan, Yemoja, Adegbayi and Moga were statistical significance, F statistics = 4.361, $p<0.05$
The mean values of PAC for Agbadagbudu, Sango, Odo-Akeu, Onipasan, Yemoja, Adegbayi and Moga were statistical significance, F statistics = 166.806, $p<0.05$

Table 4.6: Comparison of Bacteriological Quality of Water Samples from Household Storage Containers

Parameter	Communities	Mean ± s.d	F statistics	P-value
Mean TAPC (cfu/ml)	Agbadagbudu	1.85 x 10^3±173.21	51.496	0.000
	Sango	1.8 x 10^3±167.33		
	Odo-Akeu	1.28 x 10^3.82±271.36		
	Onipasin	1.17 x 10^3±57.74		
	Yemoja-Olodo	1.85 x 10^3±173.21		
	Adegbayi	3.03 x 10^3±208.17		
	Moga	1.03 x 10^3±86.6		
Mean TCC (MPN/100ml)	Agbadagbudu	0.13 x 10^3±36.97	3.395	0.010
	Sango	0.13 x 10^3±29.44		
	Odo-Akeu	0.3 x 10^3±208.17		
	Onipasin	0.14±34.64		
	Yemoja-Olodo	o.13 x 10^3±36.97		
	Adegbayi	0.2 x 10^3±11.55		
	Moga	92.22±21.67		
Mean *E.coli* count (MPN/100ml)	Agbadagbudu	0.0005 x 10^3±0.58	4.361	0.002
	Sango	0.003 x 10^3±0.52		
	Odo-Akeu	0.001 x 10^3±3.27		
	Onipasin	0.001 x 10^3±1.73		
	Yemoja-Olodo	0.132 x 10^3±132		
	Adegbayi	0.72 x 10^3±935.31		
	Moga	0.01 x 10^3±13.23		
Mean PAC (cfu/ml)	Agbadagbudu	ND	166.806	0.000
	Sango	ND		
	Odo-Akeu	0.001 x 10^3±1.55		
	Onipasin	ND		
	Yemoja-Olodo	ND		
	Adegbayi	0.017 x 10^3±0.58		
	Moga	0.00078 x 10^3±0.44		

ND- Not Detected

4.4 Sanitary Inspections of Springs and Household Storage Containers

4.4.1 Sanitary Status of Springs

Table 4.7 shows the sanitary status of the protected springs during the dry and rainy seasons. For both seasons, all the springs showed a risk of contamination. Odo-Akeu had the least sanitary risk score of 2, indicating low risk to the consumers. The highest risks were observed during the rainy season in Moga, Sango and Odo-Akeu.

4.4.2 Risk Determination of Springs

Table 4.8 shows the combined risk analysis of the sanitary risk scores and *E.coli* count for the spring sites during the dry and rainy seasons. During the dry and rainy seasons, Yemoja, Adegbayi and Sango were grossly polluted as evidenced by the results of the *E.coli* count (0.7 x 10^3, 1.8x 10^3) MPN/100ml, (0.6x 10^3, 1.8x 10^3) MPN/100ml and (0.35x 10^3, 1.8x 10^3) MPN/100ml respectively. However, Adegbayi had a sanitary risk score of 5 and 6 during the dry and rainy seasons respectively, indicating intermediate to high risk of water contamination.

The highest risks of water contamination with a corresponding gross pollution as indicated by the sanitary scores and *E.coli* count were obtained from Yemoja, Onipasan and Sango during the dry season. Similarly, the highest risks of water contamination during the rainy season were obtained from Yemoja Moga and Sango (Figure 4.3)

Positive correlation (0.441) exists between mean sanitary risk score (8±1.9) and *E.coli* count (1x 10^3±231.05) MPN/100ml, during the rainy season. Negative correlation (-0.275) exists between mean sanitary risk score (6.14±2.34) and *E.coli* count (0.53x 10^3±130.38) MPN/100ml, during the dry season (Table 4.8).

Table 4.7: Sanitary Status of Springs during Dry and Rainy Seasons

Spring sources	Season	Sanitary risk score	Level of Risk
Yemoja-Olodo	Dry	7	Very high risk
Adegbayi		5	Intermediate to high risk
Moga		9	Very high risk
Agbadagbudu		5	Intermediate to high risk
Onipasan		7	Very high risk
Sango		8	Very high risk
Odo-Akeu		2	Low risk
Yemoja-Olodo	Rainy	9	Very high risk
Adegbayi		6	Intermediate to high risk
Moga		10	Very high risk
Agbadagbudu		6	Intermediate to high risk
Onipasan		6	Intermediate to high risk
Sango		10	Very high risk
Odo-Akeu		10	Very high risk

Table 4.9: Combined Risk Analysis of the Sanitary Risk Scores and *E.Coli* Count for the Spring Sites During the Dry and Rainy Seasons.

Spring sources	Season	Sanitary risk score	Level of Risk	*E.coli* COUNT (MPN/100ml)	*CATEGORY	*QUALITY REMARK	Correlation co-efficient
Yemoja-Olodo	Dry	7	Very high risk	0.7×10^3	D	Gross pollution	0.441
Adegbayi		5	Intermediate to high risk	0.6×10^3	D	Gross pollution	
Moga		9	Very high risk	0	A	No pollution	
Agbadagbudu		5	Intermediate to high risk	0	A	No pollution	
Onipasin		7	Very high risk	0.5×10^3	D	Gross pollution	
Sango		8	Very high risk	0.35×10^3	D	Gross pollution	
Odo-Akeu		2	Low risk	0.5×10^3	D	Gross pollution	
Yemoja-Olodo	Rainy	9	Very high risk	1.8×10^3	E	Gross pollution	-0.275
Adegbayi		6	Intermediate to high risk	1.8×10^3	E	Gross pollution	
Moga		10	Very high risk	1×10^3	D	Gross pollution	
Agbadagbudu		6	Intermediate to high risk	0.02×10^3	C	Intermediate pollution	
Onipasin		6	Intermediate to high risk	0.02×10^3	C	Intermediate pollution	
Sango		10	Very high risk	1.8×10^3	E	Gross pollution	
Odo-Akeu		10	Very high risk	0.03×10^3	C	Intermediate pollution	

0	1	2	3	4	5	6	7	8	≥9
E						SP6 (R)			SP2 (R) SP5 (R)
D		SP3 (D)				SP6 (D)	SP4 (D) SP5 (D)	SP2 (D)	SP7 (R)
C					SP1 (R)	SP4 (R)			SP3 (R)
B									
A					SP1 (D)				SP7 (D)
No risk No action	**Low risk Low action priority**			**Intermediate to high risk Higher action priority**			**Very high risk Urgent action priority**		

Code: SP1(D): Agbadagbudu dry season; **SP1 (R):** Agbadagbudu rainy season; **SP2 (D):** Sango dry season; **SP2 (R):** Sango rainy season; **SP3 (D):** Odo-Akeu dry season; **SP3 (R):** Odo-Akeu rainy season; **SP4 (D):** Onipasin dry season; **SP4 (R):** Onipasin rainy season; **SP5 (D):** Yemoja dry season; **SP5 (R):** Yemoja rainy season; **SP6 (D):** Adegbayi dry season; **SP6 (R):** Adegbayi rainy season; **SP7 (D):** Moga dry season; **SP7 (R):** Moga rainy season

Figure 4.3: Combined risk analysis of sanitary risk score and *E.coli* count of the seven (7) protected springs during dry and rainy seasons

4.4.3 Sanitary Status of Household Water Storage Containers

Table 4.9 shows sanitary status of household water storage containers for communities who use protected springs. The least mean sanitary risk score of 3.6 ± 0.2, was observed from the water storage containers of households that use Onipasan natural spring. This implies that there is a low risk of water contamination from the households that use Onipasan natural spring. The household water storage containers from the users of other springs had intermediate to high risk of contamination.

4.4.4 Risk Determination of Household Water Storage Containers

The risk determination of household water storage containers is shown in Table 4.10. The household water storage containers in Yemoja and Adegbayi indicated gross pollution with mean *E.coli* count of (0.13x 10^3±21.4 and 0.72x 10^3±43.61)MPN/100mls respectively.

Negative correlation (-0.0072) exists between mean sanitary risk score and *E.coli* count (Table 4.10).

Table 4.9: Sanitary Status of Household water storage containers

Location	Sanitary risk score	Level of Risk
Agbadagbudu	5 ± 0.2	Intermediate risk
Sango	5 ± 1.3	Intermediate risk
Odo-Akeu	5 ± 0.9	Intermediate risk
Onipasan	3.6 ± 0.2	Low risk
Yemoja-Olodo	4.75 ± 1.13	Intermediate risk
Adegbayi	4.67 ± 0.81	Intermediate risk
Moga	4.89 ± 1.02	Intermediate risk

Table 4.10: Risk Determination of Household Water Storage Containers.

Location	Mean sanitary risk score	Risk classification	Mean *E.coli* count (MPN/100ml)	Category	Quality remarks	Correlation coefficient (R)
Agbadagbudu	5 ± 0.2	Intermediate risk	$0.0005 \times 10^{3} \pm 0.05$	B	Low pollution	
Sango	5 ± 1.3	Intermediate risk	$0.018 \times 10^{3} \pm 3.7$	C	Intermediate pollution	
Odo-Akeu	5 ± 0.9	Intermediate risk	$0.001 \times 10^{3} \pm 0.4$	B	Low pollution	
Onipasin	3.6 ± 0.2	Low risk	$0.001 \times 10^{3} \pm 0.11$	B	Low pollution	
Yemoja-Olodo	4.75 ± 1.13	Intermediate risk	$0.132 \times 10^{3} \pm 21.4$	D	Gross pollution	-0.0072
Adegbayi	4.67 ± 0.81	Intermediate risk	$0.720 \times 10^{3} \pm 43.61$	D	Gross pollution	
Moga	4.89 ± 1.02	Intermediate risk	$0.018 \times 10^{3} \pm 6.2$	C	Intermediate pollution	

Plate 4.13: Interviewer, translator and women group after the focus group discussion.

4.5 Community Survey

4.5.1 Socio-Demographic Characteristics of Natural Spring Users

A total of 400 respondents were surveyed for the study. The mean age of the respondents was 38±14 years, with a range of 14 to 90 years (Figure 4.4). Three hundred and thirty-four (83.4%) of the respondents were women. Two hundred and ninety-six (74%) were married, 72 (18%) were single, 7 (1.8%) were separated, while 25 (6.3%) were widowed. Most of the respondents (98.5%) were Yoruba. More than half of the respondents (56.5%) practice Islam while 43.5% were Christians (Table 4.11).

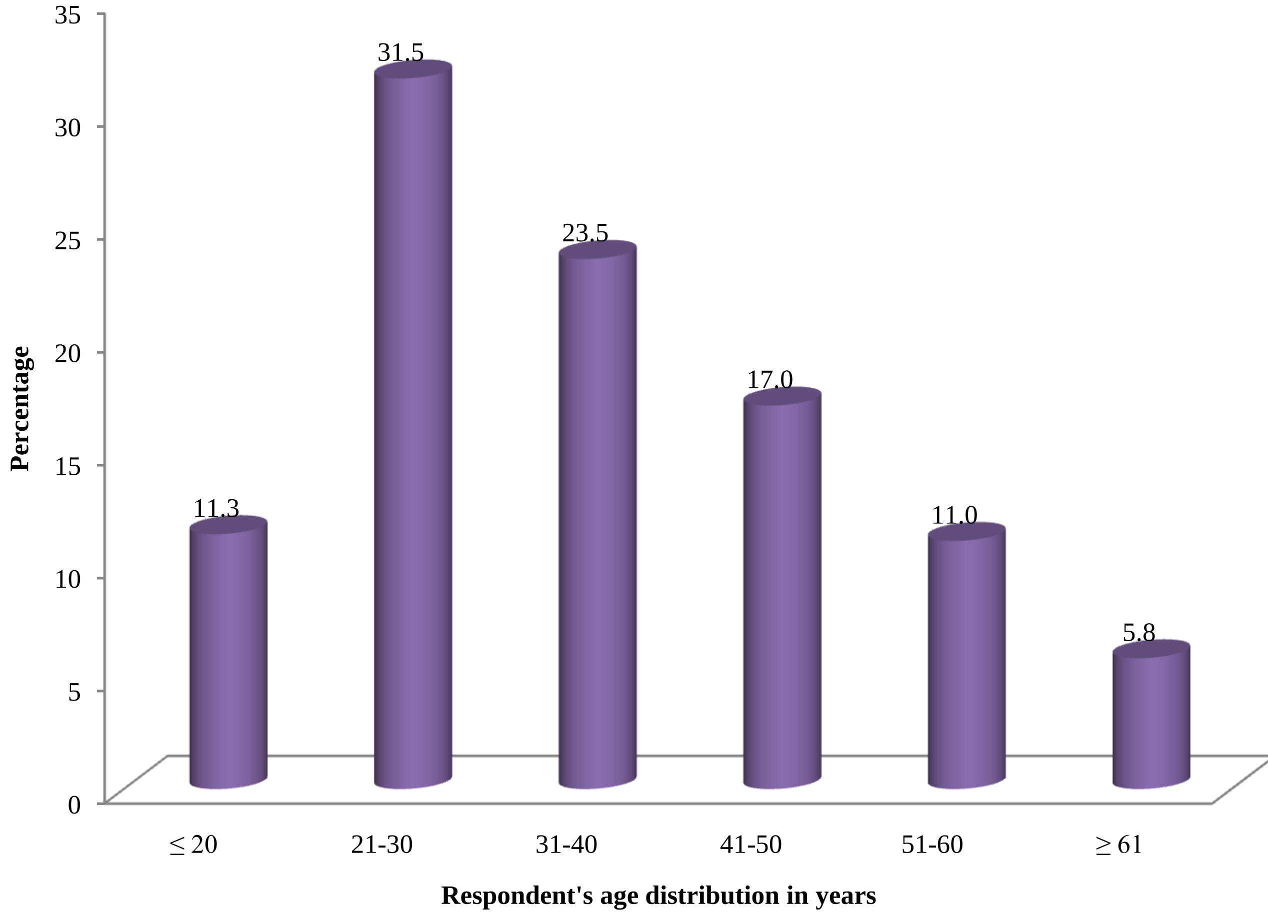
Majority of the respondents (47.9%) hadsecondary school education, 23.5% completed primary education, 11.6% received tertiary education, 0.7% had Islamic education, while 16.9% had no formal education (Figure 4.5)

Almost half (49%) of the respondents were housewives, 15% were self-employed, 11% were artisans while 8% and 3.8% were civil servants and professionals (Figure 4.6).

One hundred and ninety-three (48.3%) of the respondents received an income of 1001 – 10000 naira per week, 17.5% received an income of 100 - 1000 naira, while 2.8%, 0.5% and 0.5% of the respondents received an income of 10001 - 20000 naira, 20001 - 30000 naira and 40001 - 50000 naira per week respectively (Table 4.11).

One hundred and fifty-nine (39.8%) contributed 5 - 100 naira daily to the spring, while 8(2%) and 1 (0.3%) of the respondents contributed between 101 - 200 naira and 401 - 500 naira daily to the springs (Table 4.11).

The age distribution of the household members was almost even. ≤5 were 19.7%, 10% were ≥60years, 27,8% were between 25-59 years, 21.7% were between the ages of 13-24 years, while 20.8% were between 6-12 years (Figure 4.4)



Mean ± SD=38.0±14 years; min=14, max=90

Figure 4.4: Age distribution of the respondents

Table 4.11: Respondent's Socio-Demographic Characteristics (N=400)

Socio-demographic features	Frequency	%
Sex		
Male	66	16.6
Female	334	83.4
Marital status		
Single	72	18
Married	296	74
Separated	7	1.8
Divorced	0	0
Widowed	25	6.3
Ethnic group		
Hausa	3	0.8
Yoruba	394	98.5
Ibo	2	0.5
Tiv	1	0.3
Religion		
Christian	174	43.5
Islam	226	56.5
Respondent's weekly income (In naira)		
100-1000	70	17.5
1001-10000	193	48.3
10001-20000	11	2.8
20001-30000	2	0.5
30001-40000	0	0.0
40001-50000	2	0.5
No response	122	30.5
Regular contribution to the spring (In naira)		
5-100	159	39.8
101-200	8	2
201-300	-	-
301-400	-	-
401-500	1	0.3
No response	232	58

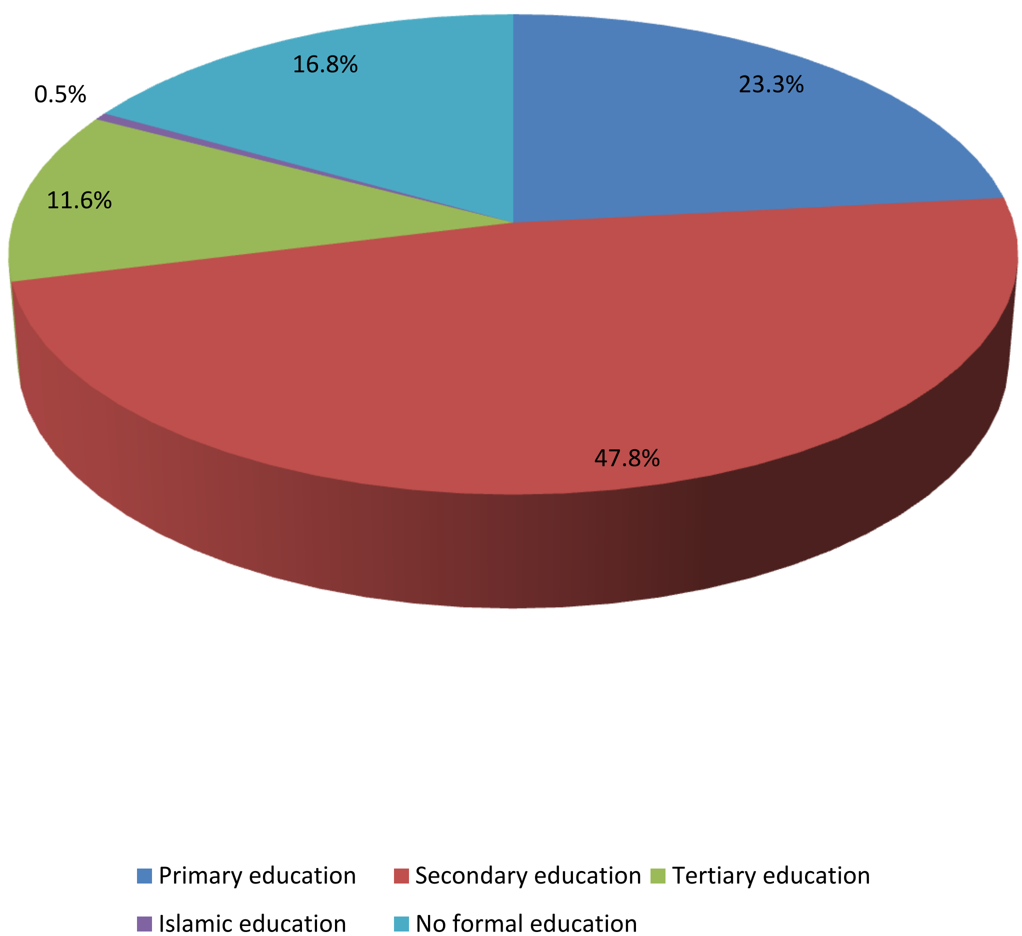
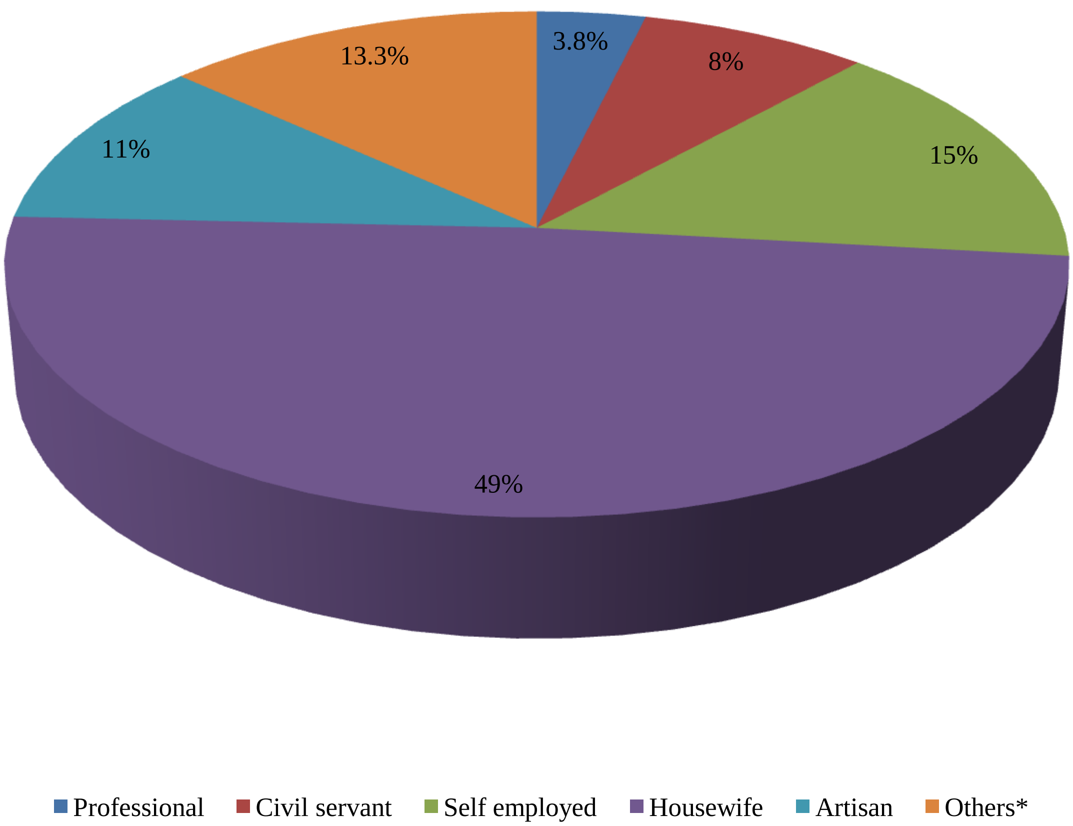


Figure 4.5: Educational qualification of respondents



***-(Farmers, hair dressers)**

Figure 4.6: Occupational status of respondents

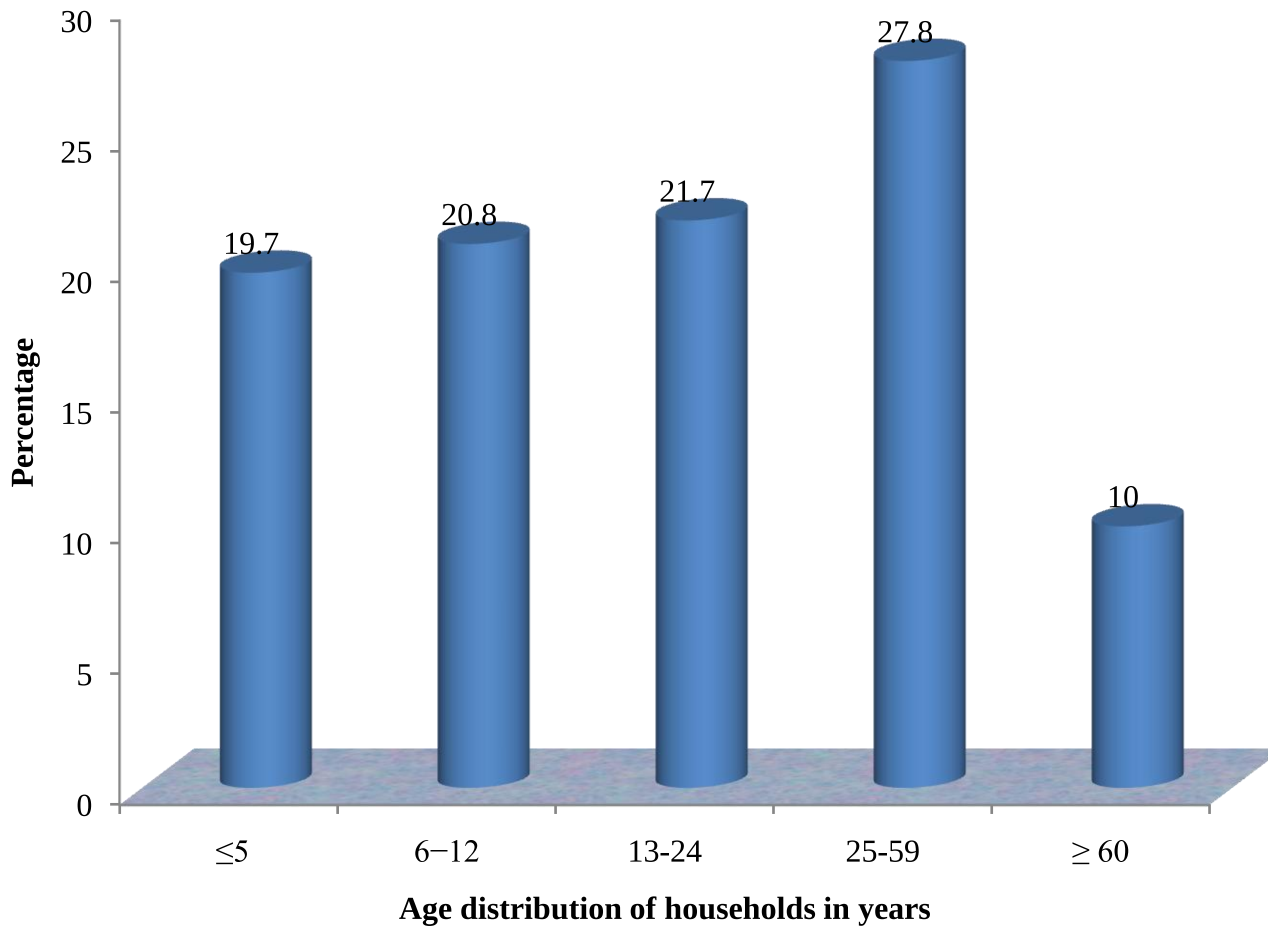


Figure 4.7: Age distribution of households

4.5.2 Knowledge on Effective Spring Utilization

4.5.2.1 Knowledge on Optimal Use

Most of the respondents (93.3%) had access to the spring. Of the respondents that stated that they had no access, 25.9% said they had a well, 14.8% stated they had children that were too young, 7.4% said they were tenants, 3.7% said only the wives fetched water from the spring, while 7.4 % said it was because of the environment (Table 4.12)

The respondents stated that the mean distance to fetch water from the spring to the house was (494.52±29.6) meters. The mean number of times water is fetched daily was 3.02±0.4 (Table 4.12)

The spring users stated that mean time it took to fetch water before the protection was (52.03±5.45) minutes, while the mean time it takes to fetch water after the protection is (20.83±1.03) minutes, $t = 10$, $p<0.05$ (Table 4.13). There was statistical significance in the time it took to fetch water before and after the protection.This result was supported by the women, who reported during the FGD that "time for fetching water is better, we fetch the water and leave whenever we come and we do not waste time again".

More than half (56.8%) of the respondents stated that they sometimes had long queues when fetching water, 38.5% said they always had long queues, while 18 (0.3%) persons said they had never experienced long queues when fetching water from the springs (Table 4.12).

Majority (71.8%) of the spring users stated that the protection of the springs have saved time, while 28.3% said there has been no time saved from the protection of the spring. Of the percentage that stated that time has been saved, almost half (49.5%) said that they have utilized the time saved for domestic activities, 33 (8.3%) persons used the time saved for business, 4.5% utilized it for their work, 1 person utilized it for education, while 2.3% engaged in other activities like sports (Table 4.14). During the FGD, the men using the spring supported the response that one of the advantage of the time saved has helped to ensure that their homes are cleaner.

The respondents reported that the mean volume of water fetched daily was (186±32.8) liters. More than half (53.8%) agreed that the volume of water has increased after the protection, while 185 (46.3%) disagreed that there has been an increase in volume after the protection. Of the total of 215 respondents that agreed that there has been an increase in volume of water after the protection, 82 stated that they utilized the increase in volume of water for domestic chores, 66 persons reported that there is an improvement in their hygiene, 8 persons used it for business, 23 respondents stated that it makes thing convenient, while 11 stated that it saved time (Table 4.14).

For the economic/ agricultural gains accruing from increased volume of water after protection, 8.4% stated that the benefits was utilized for farming, 49.2% used the gains in better nutrition, 28.4% reared livestock, while 8.4% was involved in some business (grinding machine, sale of pure water) (Figure 4.8).

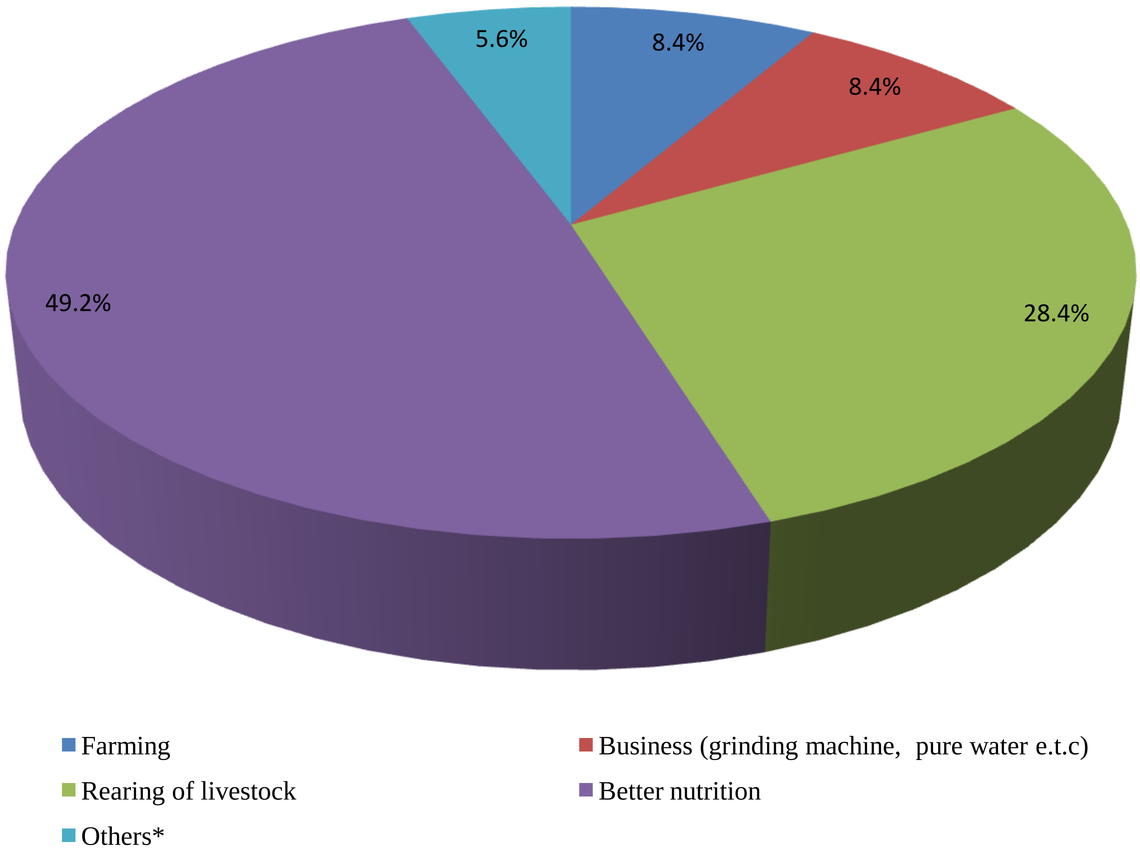
Three hundred and eighty respondents stated that they use the spring water for washing clothes, 378 (26.6%) said they clean their homes with the water, 0.9% stated that they do some form of business with the water, 291 (20.6%) stated that they drink it, while 25.2% said they cook with it (Table 4.14)

Table 4.12: Optimal Spring Use

Variables	Frequency	%
Access to the spring by everyone		
Yes	373	93.3
No	27	6.8
Reasons for no access to spring		
Presence of well in the house	7	25.9
Too young children	4	14.8
Tenants	2	7.4
Only wife has access	1	3.7
Environment	2	7.4
No response	11	40.8
Mean distance from spring to house (meters)	494.52±29.6	
Mean number of times water is fetched daily	3.02±0.4	
Having long queues for fetching water		
Sometimes	227	56.8
Always	154	38.5
Never	18	4.5
No response	1	0.3

Table 4.13: Comparison of Time it Takes Respondents to Fetch Water Before and After the Rehabilitation/Protection

Time it takes respondents to fetch water	Mean ± s.d	t-test	P value
Before the protection/rehabilitation	52.03±5.45	10.125	0.000
After the protection/rehabilitation	20.83±1.03		



***- Alabaru (carrying load), Hair making**

Figure 4.8: Economic/agricultural gains attributed to increase in water volume

Table 4.14: Optimal Water Use at Households

Variables	Frequency	%
Saved time from fetching water		
Yes	287	71.8
No	113	28.2
Activities from the saved time		
Domestic	198	49.5
Business	33	8.3
Work	18	4.5
Relaxation	8	2
Study	1	0.3
Other activities	9	2.3
No response	20	5
Mean volume of water fetched daily (liters)	186±32.8	
Increase in water volume after protection		
Yes	215	53.8
No	185	46.2
Benefits of increased volume		
Domestic	82	20.5
Better nutrition	66	16.5
Business	8	2
Convenience	23	5.8
Saves time	11	2.8
No response	25	6.4
Water uses		
Cooking	359	25.2
Drinking	291	20.6
Business (sale of pure water and ice block e.t.c)	13	0.9
Washing	380	26.7
Cleaning	378	26.6

4.5.2.2 Knowledge on hygienic use

Majority (98%) of the respondents stated that they used plastic containers for fetching water from the spring, while 1.8% and 0.2% said they used clay pots and metal containers in fetching water respectively. More than half (55%) of the respondents said that their containers for fetching water had no cover, while 180 (44%) persons stated that their containers for fetching water had covers (Table 4.15).

Three hundred and sixty-one (90.3%) respondents stated that they used plastic containers in storing water at home, while 34 and 5 respondents stated that they used clay pots and metal containers in storing water at home. Most (93.5%) of the respondents stated that their water storage containers had covers, while 26 persons said that their water storage containers had no covers. One hundred and thirty-six respondents stated that they wash their water storage containers every day, while 237 and 27 respondents said they washed their water storage containers on alternate days and only when dirty respectively (Table 4.15).

Almost all (99%) the respondents said that they had a ladle for drawing water from the storage containers, while only 4 persons had no ladles. Of the proportion of respondents that had ladle, 288 used plastic cups, 54 used bowls, 4 used calabash, while 8 used stainless cup. Forty (10.2%) respondents stated that they washed the ladles every day, 138 said they washed them on alternate days, while 218 washed the ladles only when dirty (Table 4.15).

Majority (61.3%) of the respondents stated that children had access to water storage containers, while 151 said that children had no access to the water storage container. Most (370) of the respondents said that they had different water storage containers for cooking/drinking from other purposes, while 29 respondents said they used the same water container for all purpose.

More than half (211) of the respondents said they had no pets or animals, while 189 said they had pets/animals. Of the proportion of respondents that had pets/animals, 17.5% said the pets/animals had access to the water storage containers, while most (82.5%) of the respondents said their pets/animals had no access to the storage containers (Table 4.16).

Two hundred and fifty-two (63%) respondents said they never treat the water, 82 respondents stated that they sometimes treat the water, while 66 said that they always treat the water. Of the proportion that practice some form of water treatment, 12% boil, 9% filter, while 20% add alum.

Most (82.3%) of the respondents said that there has been some improvements in the hygiene practices because of the spring protection. Of this proportion, 195 stated that good hygiene was a benefit, 29 said domestic was a benefit, while 69 respondents stated that improved health was one of the hygienic benefits accruing from the spring protection (Table 4.16).

Table 4.15: Hygienic Use of Water Containers

Variables	Frequency	Percentage
Container type for fetching water from spring		
Plastic	392	98
Clay pots	7	1.8
Metal	1	0.2
Presence of cover for water-fetching container		
Yes	180	45
No	220	55
Container type for water storage at homes		
Plastic	361	90.3
Clay pots	34	8.5
Metal	5	1.3
Presence of cover for water storage container		
Yes	374	93.5
No	26	6.5
Washing of water storage container		
Everyday	136	33
Alternate days	237	60.2
Only when dirty	27	6.8
Presence of ladle used to obtain water from the water storage container		
Yes	396	99
No	4	1
Type of ladle used to obtain water from the water storage container		
Plastic cup	288	72
Bowl	54	13.5
Calabash	4	1
Stainless cup	8	2.5
No response	42	10.5
Washing of ladle used to obtain water from the water storage container		
Every day	40	10.2
Alternate day	138	34.8
Only when dirty	218	55

Table 4.16: Hygienic Water Handling Practices at Home

Variables	Frequency	%
Access of children to storage container		
Yes	245	61.3
No	151	37.8
No response	4	1
Different water storage container for cooking/drinking from other purposes		
Yes	370	92.5
No	29	7.3
No response	1	0.3
Presence of pets and animals		
Yes	189	47.3
No	211	52.8
Access of pets/animals to water storage containers		
Yes	33	17.5
No	156	82.5
Water treatment practices		
Sometimes	66	16.5
Always	82	20.5
Never	252	63
Type of treatment used		
Boiling	48	29.27
Filtration	36	21.95
Addition of alum/other chemicals	80	48.78
Better hygiene practices accruing from spring protection		
Yes	329	82.3
No	71	17.8
Hygienic benefits of spring protection		
Good hygiene	195	59.3
Domestic	29	8.8
Improved health	69	21
No response	36	10.9

4.5.2.3 Knowledge on Consistent Use

Fifty-three (5.38%) persons stated that there are streams/rivers present in the community, 331 said they had access to wells, 56 said they had boreholes, while 110 said they had access to pipe borne water. Twenty-two (3.1%) respondents said they preferred streams/rivers before the spring protection, 235 stated that they preferred wells, while 210 and 128 stated they preferred rain water and spring before the protection of the spring respectively. After the protection of the spring, the highest proportion (197) of the respondents stated that they preferred rain water, 176 said they preferred the spring water, 186 said they preferred wells, 57 said they preferred pipe borne water, while 31 and 22 respondents stated that they preferred water vendor and boreholes (Table 4.17). During the FGD, the women said "we prefer the natural water because we use the water for everything unlike the other sources that we cannot drink or cook with".

Most (92.8) of the respondents reported that they never mix the water from all the sources, 19 persons stated that they sometimes mix the water, while 0.8% of the respondents reported that they always mix the water from all the sources they use (Table 4.17)

A high (88.8%) proportion of the respondents stated that they fetch water at anytime of their choice, while 11.3% reported that they can only fetch water at the time the springs are open to the public. Two hundred and ninety (72.5%) respondents stated that they preferred to fetch water in the morning, 54 reported that evenings was their preferred time for fetching water, while 15 (3.8%) stated that they fetch water at their convenience (Table 4.18).Most (309) of the respondents stated that they had water shortages during dry season. Three hundred and sixty-two (90.5%) of the respondents said that dry season was their season of highest water use, 13 persons said rainy season, while 19 (4.8%) reported that they used water equally during both seasons (Table 4.18).

Table 4.17: Water Sources in the Community

Variables	Frequency	(%)
Presence of other water sources		
Stream/river	53	5.38
Well	331	33.6
Borehole	56	5.69
Water vendor	82	8.33
Rain water	353	35.83
Pipe borne water	110	11.17
Preferred source of water before spring protection		
Stream/river	22	3.1
Well	235	33.6
Borehole	24	3.4
Water vendor	18	2.6
Rain water	210	30
Spring	128	18.6
Pipe borne water	61	8.7
Preferred source of water after spring protection		
Stream/river	9	1.3
Well	186	27.4
Borehole	22	3.2
Water vendor	31	4.6
Rain water	197	29.1
Spring	176	26
Pipe borne water	57	8.4
Mixture of water from all sources		
Sometimes	19	4.8
Always	3	0.8
Never	371	92.8
No response	7	1.8

Table 4.18: Time for Water Use

Variables	Frequency	%
Ability to fetch water at anytime		
Yes	355	88.8
No	45	11.3
Preferred time for fetching water		
Morning	290	72.5
Evening	54	13.5
Convenient time	15	3.8
Every time	12	3
Afternoon	21	5.3
No response	8	2
Seasonal water shortages		
Rainy	1	0.2
Dry	309	77.3
No response	90	22.5
Season of highest water use		
Dry	362	90.5
Rainy	13	3.3
Both seasons	19	4.8
No response	6	1.5

4.5.3 Knowledge on Health Status

Thirty-five (30.43%) respondents reported that there was malaria outbreaks before the spring protection, 32 said there was outbreak of thypoid, while 21 stated that there was diarroheal infection outbreak before the spring was protected. Most (90.5%) of the respondents stated that there has been no disease occurrence after the spring protection. Of the proportion of respondents that reported that there was occurrence of disease after the spring was protected, 13 persons were children under 5 years, 19 were children between (6- 12) years, while 6 were adults (25-29) years. Of the proportion of respondents that had disease after spring protection, 5 (13.2%) of the respondents reported deaths from the disease outbreak (Table 4.19). the discussants during the FGD said that the water had healing powers and that they were not aware of any death reports.

Thirty-two (84.2%) of the total proportion of respondents that reported that there was disease outbreak said they seek help when they were sick. Of this number, 10 were prompted to seek help when they were sick, 3.12% were prompted to seek help when it was urgent and 1 person when the sickness got worse. Twenty-seven (84%) respondents reported that they sought medical attention from hospitals when they were sick, while 3 (9.37%) and 2 (6.25%) persons reported that they sought help from chemist and clinics when they were sick. More than half (59.37%) of the proportion of persons that were sick frequently sought medical attention, 3 persons sought help when sick, while 6 (18.77%) persons sought help once in a while (Table 4.20).

Table 4.19: Disease Outbreak

Variables	Frequency	Percentage
Disease outbreak before spring protection from water use		
Malaria	35	30.43
Thypoid	32	27.83
Skin rashes	24	20.87
Diarrohea	21	18.26
Other	3	2.61
Disease occurrence after spring protection		
Yes	38	9.5
No	362	90.5
Age of affected persons (years)		
Under 5's (≤5)	13	3.3
Children (6-12)	19	4.8
Adults (25-59)	6	1.5
Deaths from disease outbreak		
Yes	5	13.2
No	33	86.8

Others – cholera and dysentery

Table 4.20: Health Seeking Behaviour

Variables	Frequency	%
Seek help when sick		
Yes	32	84.2
No	6	15.8
Promptings to seek help		
Sickness	10	31.25
Difficulty	17	53.14
Urgency	1	3.12
Gets worse	1	3.12
No response	3	9.37
Places where medical attention was sought		
Clinic	2	6.25
Hospital	27	84.38
Chemist	3	9.37
Frequency of medical visits		
Frequently	19	59.37
Twice a week	3	9.37
When sick	3	9.37
Necessity	1	3.12
Once in a while	6	18.77

CHAPTER FIVE

DISCUSSION

Inadequate and poor quality of drinking water is regarded as one of the world's major causes of preventable morbidity and mortality. Potable water should appeal to consumers and should also be free from contamination of all sorts. Often than not, this is not usually obtainable because of the great property of water as a universal and excellent solvent and a vehicle for transmission of substances with resultant pollution from the different sources.

5.1 Quality of Water from Protected Springs

This study showed that the result of the physico-chemical analysis of the springs was of good quality, as most of the parameters were within the limits of the recommending agencies.

There were slight variations in the pH values for Sango (5.1±0.9 and 5.45±0.07) and Onipasan (5.7±0.6 and 5.65±0.07) during the dry and rainy seasons respectively. These showed pH values lower than 6.5-8.5 as recommended by WHO and SON; hence, making the water slightly acidic. Such low values in the pH were also observed in water samples from Agbadagbudu (5±1.3) and Adegbayi (5.7±0.8) during the rainy season. The low pH observed in some of these springs could have been as a consequence of carbon dioxide saturation in the groundwater. In a research conducted by Byamukama*et al*,(1999), he reported that soils contain high concentrations of carbondioxide which dissolves in the groundwater, hence, creating a weak acid capable of dissolving any silicate mineral. These fluctuations in pH may lead to an increase or decrease in the toxicity of poisons in water bodies (Ali, 1991). Although pH has no direct impact on consumers, it is one of the most important operational water quality parameters.

The pH of Agbadagbudu and Adegbayi had values below the recommended limit during the rainy season, while Sango and Onipasan had values below the recommended limit for both dry and rainy season. This implies that the water obtained from these springs at that time was slightly acidic. The lower the value of the total hardness, gave a correspondingly low values for the pH.

Another association was shown to exist between the total dissolved solids and the electrical conductivity. The highest values of the total dissolved solids were obtained from Sango for dry (395mg/L) and rainy season (480mg/L); and the highest values of electrical conductivity were obtained from Sango for dry (175 µS) and rainy (789 µS) seasons. Hence, higher values of total dissolved solids where obtained from water samples with high electrical conductivity.

During the dry season, the results of the electrical conductivity for the springs were within the recommended limit of 400µS/cm stipulated by the WHO. During the rainy season, all springs except Odo-Akeu (777±9.4) µS/cm, Agbadagbudu (437.5±4.95) µS/cm and Sango (789±11.3) µS/cm, had values greater than the recommended limit. For the higher the values of the total dissolved solid, gave a corresponding increase in the values of electrical conductivity. The electrical conductivity increases with more ions in the water. These findings were supported by Harter, 2003, who reported that there exists a relationship between electrical conductivity and total dissolved solid, because by measuring the water's electrical conductivity, the total dissolved solid can be determined and as such, at a high total dissolved solid concentration, the water becomes saline. Owing to the differences in the solubilities of minerals, the concentrations of TDS in water vary. These results obtained from Sango could be explained by the presence of a large expanse of land beside the spring which is used as a dump site by carpenters and also as an open site where people defecate.

For both seasons, the mean turbidity values for all springs were within the recommended limit of 5NTU by WHO, except Yemoja- Olodo, which had a mean value of (7±3.1) NTU during the rainy season. The value obtained from Yemoja-Olodo is not surprising, owing to the fact that the water sample collected from this source during the rainy season was visibly unclear.

The values obtained from the analysis of nitrate from these springs showed higher values during the rainy season as compared to dry season, except for Onipasan (12 and 7.7mg/L) and Adegbayi (9.9 and 8.7mg/L) where the results of the dry season was higher than the rainy seasons respectively. These results agree with Howard (2002), who believes that nitrate concentration may show seasonal peaks; with higher values obtained as wet season progresses and declining during dry season. The concentration of nitrate in groundwater is normally low but can reach high levels as a result of leaching or runoff from agricultural land or contamination from human or animal wastes (WHO 2006; Lewis *et al*, 1980).

All the heavy metal parameters had excellent results, with only lead being on the borderline of 0.01mg/l which was recommended by the regulatory agencies. The results showed that all the values that were obtained for lead were within the maximum recommended limit of 0.01mg/L. During dry and rainy seasons, lead was found to be present in the water samples from Sango. The presence of lead in the water sample from Sango could be as a result of the huge expanse of land beside the spring used as a refuse dump site. Leacheate from these refuse containing lead could infiltrate into the ground and move to the water table, thus, polluting the water.

Lead was also found in samples fromOnipasan and Yemoja-Olodo during the rainy season, while Adegbayi showed the presence of lead during the dry season. These values obtained could be attributed to the prevailing economic activities around the environs of the spring. Onipasan and Adegbayi are located close to mechanic workshops and battery charger business. This explains the presence of lead in the spring water, because it is used principally in the production of lead-acid batteries, solder and alloys (WHO, 2006). Depending on the level and duration of exposure, intake of lead can result in a wide range of biological effects. Exposure to lead could lead to problems in the synthesis of haemoglobin and affect the reproductive and nervous systems.

5.2 Bacteriological Quality of Water Samples from Protected Springs.

From the result of this study, it shows that the bacteriological quality of water from these protected springs were poor owing to the prevailing environmental and sanitary conditions. The values obtained for the analysis of TAPC during the dry season ranges from (7.55 x 10^{3}- 2.5x $10^{3)}$cfu/ml, with Moga having the least value and Yemoja-Olodo with the highest value; and from (5.15x 10^{3}- 25x 10^{3})cfu/ml during the rainy season, with Odo-Akeu with the least value and Onipasan with the highest value.

During the dry season, only 2 springs showed presence of *Pseudomonas aeruginosa*, with the highest value obtained in Adegbayi. *Pseudomonas aeruginosa* was found in all the springs during the rainy season, thus implying that the worst contamination troubles usually come during the rainy season, when infiltrating water carries the waste directly to the groundwater supply. This is corroborated by Soutter (1998), who observed that the worst contamination occurs during the rainy season.

For both seasons, all the water samples had faecal coliform counts above the WHO guideline. The ranges of TCC were from 1150 to 10500MPN/100ml during the dry season and (0.75x 10^{3} to 11x 10^{3})MPN/100ml during the rainy season. The presence of very high TCC in all the spring water samples indicate gross pollution of these sources, which could be associated with the prevailing poor environmental and sanitary conditions as depicted by the sanitary inspection results. Refuse dumps, faeces, smell of urine, waste disposal site upstream of the springs, flowing and stagnant water which was observed close to these springs could account for the pollution and high bacterial load.

In this study, the bacterial faecal indicator, *E. coli,* was used to provide an insight into the water quality from the various springs and households.Thepresence of *E. coli* in drinking water denotes that the water has been faecallycontaminated and therefore presents a potential risk of excreta related diseases. Safedrinking water should have nil *E. coli* in 100 ml of water (WHO, 1993b; WHO 1997). The bacteriological quality of these springs is comparable to similar studies carried out earlier in Ibadan (Itah*et al.*, 2006; Oloruntoba and Sridhar, 2007).

The bacteriological quality of Agbadagbudu and Moga showed acceptable results that conformed to the recommended standard during the dry season. The highest value (1x 10^3±282.84 MPN/100ml) was obtained from Onipasan, which could be as a result of the unsanitary surroundings of the spring. During the rainy season, all the springs showed *E.coli* values that were not in conformity with the acceptable limits, with a range of (0.02x 10^3- 1.80x 10^3) MPN/100ml. The highest values were obtained from Yemoja- Olodo, Adegbayi and Sango. This could be as a result of infiltration of leachate in the groundwater, contaminating it. This implies that groundwater deteriorates during the rainy season, as supported by Soutter (1998).

The detection of faecal coliform bacteria, *E. coli* in some samples is of particular concern. The presence of *E. coli* in these samples implies faecal contamination of such samples and strongly suggests the possible presence of enteric pathogenic bacteria. According to Oloruntoba (2008), detection of *E. coli* in groundwater sources is an indication of recent and potentially dangerous faecal pollution which may be as a result of infiltration of runoff into the sources.

5.3 Bacteriological Quality of Water Samples from Household Storage Containers

The water samples collected from the households were of good bacteriological quality in comparison to their various sources. A common hazard of household water is contamination by potentially harmful bacteria and other micro-organisms. The water samples collected from the storage vessels at home had better bacteriological quality than the sources where the water was drawn from. In support of the findings of this study, Woods (1984) reported that the duration of water storage also had a positive effect on bacteriological quality of stored water. It was indicated that the reduction of microorganisms in storage vessels is achieved mainly because microorganisms are likely to settle in the bottom together with particles when water is stored in a container. Storing water for as little as a few hours will sediment the large, dense particles, such as inorganic sands and silts and large microbes WHO (2009).In addition, it could also be as a result of die-off because these microorganisms are not in the natural habitat. Exposure to UV-light from the sun could also lead to reduction in the number of these microorganisms. However, overall reduction of bacteria is about 90%, especially with longer storage times of 1-2 days.These reports supports the findings of this study, were the indicator bacteria, mean *E.coli* count for the households were greatly reduced from the source to the household.

The testing of water stored in households is important to ascertain the quality of water actually being consumed. This is because post-source deterioration in quality may have occurred and therefore good quality water at source may have become severely degraded by the time it is consumed and remedial actions may be required (Robertson *et al*., 2004).

In contrast to the findings of this study, Sutton and Dominic (1989), reported that initially coliform-free water in rural Zambia were contaminated due to the way in which the water was drawn, the method of its transport to homes and the storage at homes. Similarly, Caincross et al, 1990 and Clasen and Bastable, 2003 stated that the need to protect water source will be defeated if the quality of the water used at home deteriorates due to poor water handling practices. Hence, the risk of water contamination during transport to and storage in the home requires close attention. Howard *et al*. (2003), reported that it is the collection, transport, storage and decanting of water that can lead to subsequent contamination.

5.4 Sanitary and Environmental Conditions of Springs

The risk factors which predisposed the springs and to contamination were identified. All (100%) the springs had different sources of pollution uphill and/or within 10m of the spring box. This was observed by the presence of refuse dumps, heaps of wood shavings, mechanic workshops e.t.c. Three (42.9%) springs had latrine uphill and/or within 30m of its surroundings. There were also indirect factors which could lead to the contamination of the springs. Two springs were unfenced, while in three (42.9%) springs animals had access within 10m of the spring source. Some of the springs were unsanitary – faulty masonry (28.8%); absent or non-functional surface water diversion ditch (85.7%).

5.5 Risk of spring water contamination

Some of the springs like Agbadagbudu and Odo-Akeu receive some treatment periodically, which explains the results of the bacteriological analysis in comparison to the other springs. This result was corroborated by the men during the FGD, who reported that the government adds chlorine to the water occasionally. The guideline (0 *E.coli* 100ml^{-1}) stipulated by the WHO makes these springs unsuitable for drinking, hence disapproving their usage by the community. Consequently, the classification scheme used in Indonesia, where the contamination of drinking water by *E. coli* was classified into 5 groups from grade A-E depending on the value of the *E. coli* count, was adopted (Lloyd, 1984). During the dry season, two (28.8%) springs were classified as Grade A (no risk to consumers), while five (71.4%) were classified as Grade D (high risk to consumers); whereas during the rainy season, three (42.9%) springs were classified as Grade C (intermediate risk to consumers), one (14.3%) was classified as Grade D (high risk to consumers), while three was classified as E (very high risk to consumers). This could be explained by water carrying waste which infiltrates into the groundwater. Soutter (1998) reported a similar occurrence in Kampala, Uganda where it was observed that the worst contamination occurs during the rainy season.

A positive correlation (0.441) was shown to exist between the mean *E. coli* count (1x 10^3±231.05) MPN/100ml and the mean sanitary risk score (8±1.9) during the rainy seasons.Lloyd and Bartman (1991) reported some correlation in a number of developing countries.By examining the faecal grading together with the sanitary inspection risk scores, it is possible to assess whether water quality and the identified risks by the inspection are broadly correlated (Howard, 2002). The correlation of mean *E. coli* count with the sanitary score showed that it is a reliable tool for preliminary risk assessment of spring water contamination with faecal bacterial organisms.

5.6 Sanitary Conditions of Household Water Storage Container

The major risk factors predisposing to contamination as observed by assessment of drinking water quality from household storage containers were identified. Most (82%) of the storage containers were kept at ground levels; eighteen (45%) of the storage containers were regularly cleaned and twenty-six (65%) of the storage containers were liable to rust, crack or leak. Six (15%) of the utensils/ladle for collecting water from the storage containers had covers, while in 28 (70%) households, the utensil used to draw water from the drinking water container was also used for drinking. In seven households, animals had access to the drinking water containers.

Although most of the water samples from the storage containers had an acceptable bacteriological result, the sanitary inspection indicated a likelihood of contamination.

5.7 Socio-demographic Characteristics of Natural Spring Users

The highest educational status for the majority of the respondents was secondary education and only a few of them having attended a tertiary institution, with a quarter having no formal education. Almost half (49%) of the respondents were housewives, although some engaged in some form of business. Socio-economic status is usually measured by determining education, income, occupation or a composite of these dimensions (Wintleby*et al.*, 1992).

5.8 Knowledge on Effective Spring Utilisation

5.8.1 Optimal Spring Use

The respondents reported that the mean distance to fetch water from was 494.52±269.6 meters. This implies that some of the spring users had longer distances to walk before they can fetch water. The distance could affect the volume of water available for use and also have an indirect effect on health and sanitation of the households. Friedrich (2012) reported that reducing the time needed to haul water from source to home can improve the health of children in Sub-Saharan Africa.

There was statistical significance ($p<0.05$) in the time for fetching water before and after the spring protection. It was supported by the women folk, who reported that they do not spend as much as they used to before the spring was protected during the FGD. This could also affect the volume of water available for use in the home, which has far-reaching consequences on health and general well-being of the household members. Pickering and Davis (2012) reported that the time burden of water fetching has been suggested to influence the volume of water collected by the households as well as the time spent on income-generating activities and child care. Friedrich (2012) also stated that longer fetching times could mean that less water is retrieved and therefore is available for hand washing and other hygienic activities or it could mean less time to care for children.

5.8.2 Benefits of Spring Protection

Health and non-health benefits accruing from improving access to safe drinking water abound. With safe and adequate supply of water, many small scale enterprises such as farming, sale of pure water, food vendors and animal husbandry, will be encouraged to improve livelihood. There is a direct positive impact in households when there is supply of adequate and safe water to meet their water demands. There will be improvements in nutrition, general cleanliness and improved health and wellbeing of household members.

Majority of the respondents reported that the spring protection had saved time, which has been utilized for other activities such as petty businesses, more time available for study and domestic chores. These findings were supported by the men during the FGD, who reported that their homes were cleaner because of more time the women dedicate to domestic chores.

More than half of the respondents stated that the volume of water available has increased after the spring protection. Availability of water improves the sanitation and general well-being of the household members. The increased volume also has some economic and agricultural gains. The respondents reported that the gains are felt in rearing of livestock, farming and in their businesses.

5.8.3 Hygienic Use of Storage Containers and Household Water Handling Practices

Majority of the respondents stated that they used plastic containers (90.3%) as water storage containers and 93.5% said the containers had covers. More than half of the respondents stated that they washed the storage containers on alternate days, while 136 said the storage containers were washed daily.

Almost all of the respondents said they had ladles for fetching water from the water storage containers, but more than half of the respondents reported that these ladles were washed only when dirty. These dirty ladles could affect the water quality in these storage containers, because of constant dipping and direct contact with water.

More than half of the respondents do not practice any form of water treatment. During the FGD, the men and women groups reported that there was no need to treat the water since the government treats the water for the occasionally, and the water was a blessing from God. Of the proportion that treated the water, 9% reported that they filter, 12% reported that they boil the water before use, while 20% said they add alum. These water treatment practices employed, although only by a few of the households, may have contributed the improved water quality obtained from the households as compared from the water sources from where they are drawn. Robertson *et al.*, (2004) stated that the rate at which water quality deteriorates can be controlled by adding a preservative (disinfectant residual).

5.9 Disease Outbreak and Health-Seeking Behaviour

During the FGD, the discussants stated that the water had healing powers and they believe the water could not cause any disease. Albeit these reports, 38 persons reported that there was an outbreak of disease from the use of these springs and they had recorded 5 deaths. Of this proportion, majority of the respondents stated that they seek help when these diseases occurred from hospitals, with more than half seeking medical attention frequently.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Water is an essential commodity that touches all facets of live, and its lack, shortage or compromised quality is always felt in great magnitude. Adequate and clean water supply has a positive effect on sustainable development. It is the essence of life and safe drinking water is a basic human right essential to all. The volume available determines the standard of living of people. Unacceptable and compromised water quality has a direct bearing on the community users. In recent years, the growth of industry, technology, population, and water use has increased the stress upon both land and water resources. Locally, the quality of ground water has been degraded. Municipal and industrial wastes and chemical fertilizers, herbicides, and pesticides not properly contained have entered the soil, infiltrated some aquifers, and degraded the groundwater quality.

Seven natural springs located in 4 LGA were analysed for physical, chemical heavy metals and bacteriological qualities. All the springs serve as sources for drinking water and other domestic activities. All, except Adegbayi are located in residential areas, thus, the users do not have to go for long distances in search of water. Although many users of the spring water depend on other sources of water, they fetch the spring water for drinking and cooking. This strengthens the fact that the water is of good quality. The water is used mostly during the dry season because the other available sources dry up. Most of the spring water samples analysed during the dry and rainy seasons, showed values that were acceptable for the physico-chemical parameters, meeting the recommended standard by regulatory agencies. However, there were slight variations observed for some of the parameters.

The protection of the spring has many positive benefits, which has been felt in the shortened duration of time spent in fetching water, the volume fetched and the quality which the community users believe is better as compared to before it was protected.

The bacteriological quality of these springs was poor, due to the prevailing environmental and sanitary conditions of springs which was observed and identified using the sanitary inspection checklist for springs. The total coliform count for all the springs during both rainy and dry season had values that exceeded the limit recommended by the regulatory agencies, indicating feacal contamination of these water sources.

The absence of the indicator bacteria, *E.coli* implies that the water was free from feacal contamination. Two springs were free from *E. coli* during the dry season. There were slight variations in the *E. coli* count during both seasons, with the rainy season having higher values of *E. coli* count, which could be as a result of infiltration of leacheates or subsurface infiltration. According to the level of contamination, the *E. coli* count was classified; with five of the springs showing high risk to the consumers during the dry season, while one and three springs showed high and very high risk to consumers respectively.

These high values obtained places the consumers at risk of contracting waterborne diseases which could lead to gastrointestinal disorders and illnesses such as gastro-enteritis, giardiasis, typhoid, dysentery, cholera and hepatitis. Risk factors making the springs liable to contamination were identified, with a great percentage of the springs being unsanitary and situated close to different sources of pollution such as mechanic workshop and refuse dumps. The feacal coliform count (*E. coli* count) and risk score was shown to be broadly correlated; such that it represents a linear relationship, that as the risk of contamination increases, the bacteriological count increases.

The water quality assessment carried out on these water samples that were collected from household water containers showed that the water samples had relatively better water quality compared to the water drawn from the springs. The sanitary risk assessment of the household storage containers identified some risk factors which may cause contamination of the water in the containers, some of which were ground level location of storage containers and unsanitary conditions of storage containers and ladles. These factors could lead to the introduction of feacal matter into the storage containers thus, predisposing the users from contracting water borne diseases.

6.2 Recommendations

1. For sustainable development to occur in any project, the community users who the projects were carried out for should be involved in the planning, implementation and evaluation. It is on this premise that the Odo-Akeu natural spring was protected by the joint efforts of the community, LGA, UNICEF and S.I.P. in 1996, as the first protected natural spring. The community users should be encouraged to own these facilities by ensuring that stipends are paid at the point of collection. This will ensure that the facilities are maintained and the water quality is improved by occasional disinfection.

2. Some defects which were observed around the spring sites could explain the high bacterial load. Some of these defects were faulty spring box and masonry and inadequate or absence of fencing of spring site. The community should select some of their members to be trained in the repair these components of the spring to reduce risk of contamination, and build a fence to protect the site. These measures will keep away animals from having access to the spring to compromise the quality.

3. In some of the springs where the surroundings of the spring were waterlogged, there should be a channel that diverts the stagnant water away, a diversion ditch. The stagnant water may pose a steady risk of contamination which could lead to an outbreak of infection.

4. The combination of the sanitary risk score and *E.coli count* gives a picture of the risk of water contamination. These springs with a high risk scores and a corresponding high *E.coli* count should be given urgent remedial action, such as treatment with chlorine.

5. It is pertinent that the spring water is assessed periodically and adequate and appropriate treatment administered. The need for water treatment should be stressed and emphasized as a training need for the community.

6. The government should train and re-train some community representatives on certain water handling techniques that will improve the health and general well-being.

7. It was observed that most of the community members use dippers and ladles to fetch water from the storage containers. This could further lead to contamination. Improved containers protect stored household water from the introduction of microbial contaminants via contact with hands, dippers, other faecally contaminated vehicles or the intrusion of vectors. The community members should be educated on the benefits of using containers with narrow openings and cost-effective ways of constructing water dispensing containers with narrow openings.

8. Household water treatment (HWT) technologies are any of a range of devices or methods employed for the purposes of treating water in the home or at the point of use in other settings. These are also known as point-of-use or point-of-entry water treatment technologies.

9. There are many simple and cost effective physical methods for Household Treatment Technologies (HWT).The community should be trained by the government, educationists, Non-governmental organisations and charity organisations and agencies on the benefits of adopting any simple and appropriate method of HWT.

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APPENDIX I

FOCUS GROUP DISCUSION GUIDE

Question	Follow Up Questions.
1. Are there any beliefs surrounding this spring and its usage?	a. Is the use of this spring restricted only to some certain communities? b. Do you have an idea of the number of people that use this spring?
2. Before the rehabilitation of this spring, what was obtainable in terms of - The length of time taken to fetch water - Volume of water fetched - Aesthetic parameters (colour, smell and taste)	a. What were the problems encountered from the use of this water source before the rehabilitation, such as - outbreak of diseases like skin rashes, dysentery, cholera, typhoid, childhood diarrhea? - the frequency of occurrence of these diseases - persons most affected during such outbreaks, under 5`s, pregnant women, the elderly, e.t.c b. What other problems were encountered from the use of the spring and how were these problems solved?
3. What prompted the community users to seek for help to have the water source rehabilitated?	a. What were the efforts made by the community to see to the construction of this site?
4. Do you like how this spring has been rehabilitated?	a. What are the things you like?

5. What is the water used for? -Cooking -Washing -Drinking -Business (Pure water and ice block) -Others (pls specify) 6. What is the impact of this project on the health and general wellbeing on your family and community?	b. How have you benefited from the rehabilitation in terms of - The time it takes to fetch water - Having more time at your disposal, what has the extra time helped you achieve personally and for your family? - Do your children, especially your daughters have time to go to school, or do they have time to work or learn to acquire some skills? - Has it improved the cleanliness of your home and surroundings? - Do you have more volume of water now than before the rehabilitation? a. After fetching this water, do you give it any form of treatment before use? - No, you use it like that - Allow it to settle, then filter - Boil - Add chemicals - Leave it for hours before use Health Impact - After the construction of this project, has there been any complaint on outbreak of diseases which may be due to the use of this rehabilitated spring? b. Non- health impact

	- Length of time it takes water to boil - Darkens cooking pot and water storage containers - Stains clothes.
7. Are there other sources of water available to this community?	a. Do you fetch water from these sources? b. Which source of water do you prefer? c. Which water source is most suitable and convenient for you.
8. What are the perceived problems after the rehabilitation of this spring, which were absent before the rehabilitation. -Too many people using it? (what problem have arisen with too many users) -Inaccessibility of the water at any time of the day.	a. What are the technical problems you have encountered after the rehabilitation - Has there been an incidence of breakdown of the facility? What is the frequency- monthly or periodically? - Did you seek other sources of water or made efforts to have the facility restored to proper functioning?
9. How is this spring being managed?	a. Do you pay some money? b. Do you pay as you fetch or periodically c. Do you think your money, has achieved the goal of managing and maintaining this facility d. Are the benefits/ advantages derived measurable to the fine paid
10. How have the people participated to the proper functioning of this rehabilitated spring?	a. Do the community users volunteer willing and regularly b. Do all persons- male, female and children

11. What are the things you will like to be done, to ensure that there is constant supply of clean potable water? 12. Do you have any other things you will like to say? Feel free and speak your mind.	participate to ensure the proper functioning of the facility c. Are there different social and local political groups which may affect the participation

APPENDIX II

SANITARY INSPECTION FORM FOR SPRINGS

I. Type of Facility

1. Date of visit --
2. Water sample taken? --------------- Sample No. -------------- Faecal coliform grade
3. Village --
4. Local Government Area ---

II. Specific Diagnostic Information for Assessment

		RANK	
		YES	**NO**
1.	Is the spring source unprotected by masonry or concrete wall or spring box (open to surface contamination)?	☐	☐
2.	Is the masonry protecting the spring source faulty?	☐	☐
3.	If there is a spring box, is there an insanitary inspection cover in the masonry?	☐	☐
4.	Does the spring box contain contaminating silt or animals?	☐	☐
5.	If there is an air vent in the masonry, is it insanitary?	☐	☐
6.	If there is an overflow pipe, is it insanitary or faulty?	☐	☐
7.	Does spilt water flood the collection area?	☐	☐
8.	Is the area around the spring unfenced or faulty?	☐	☐
9.	Can animals have access within 10m of the spring source?	☐	☐
10.	Is there a latrine uphill and/or within 30m of the spring?	☐	☐
11.	Does surface water collect uphill of the spring?	☐	☐
12.	Is the spring lacking a surface diversion ditch above it, or (if present) is it non-functional?	☐	☐
13.	Are there any other source of pollution uphill and/ or within 10m of the spring? (Specify).	☐	☐

APPENDIX III

SANITARY INSPECTION FORM FOR HOUSEHOLD WATER STORAGE CONTAINER

I. General Information

a. Village: --
b. Container/ water source code: --------------------------
c. Community: --
d. Local Government Area: --------------------------------
e. Date and Time of Visit: ---------------------------------
f. State: ---

II. Specific Diagnostic Information for Assessment	**Risk**
1. Are containers used for collecting water clean or rusted?	Y/N
2. Is it used to store any other liquid?	Y/N
3. Does the container used for collecting water have cover and being used?	Y/N
4. Is the container used for fetching water also used for washing/ bathing and other activities?	Y/N
5. Is the water storage container kept at ground level?	Y/N
6. Storage containers (community/ household) regularly cleaned and disinfected?	Y/N
7. Is the storage container liable to rust, crack, leaking or in-sanitary?	Y/N
8. Is the utensil used to draw water from the drinking container also used for drinking?	Y/N
9. Is the area around the storage container in-sanitary?	Y/N
10. Do animals have access to drinking water container?	Y/N

Total Score of Risks --------

III. Results and Comments

a. Risk score (Tick appropriate)

9- 10 = very high	6- 8 = high	3- 5 = medium	0- 2 = low

b. The following important points of risk were noted:

--- (list nos. 1-10).

c. Additional comment (continue on back of the form if necessary).

Name of Analyst (PRINT, signature and date) ______________________________

APPENDIX IV

QUESTIONNAIRE

Please answer the following questions by ticking any of the alternative responses or filling the blank space which best applies to you.

SECTION A
SOCIO-DEMOGRAPHIC INFORMATION

1. Age…………………………………………….

2. Sex   a. Male [ ]   b. Female [ ]

3. Marital Status

   a. Single [ ] b. Married [ ] c. Separated [ ] d. Divorced [ ]

   e. Widowed. [ ]

4. Ethnic Group

   a. Hausa [ ] b. Yoruba [ ] c. Ibo [ ] d. Others (specify) [ ]

5. Religion

   a. Christian [ ] b. Islam [ ] c. Traditional [ ] d. Others (specify) [ ]

6. Educational Status

   a. Primary education [ ] b. Secondary education [ ]

   c.Tertiary education [ ] d. Islamic school [ ] e. No formal education [ ]

7. Occupational Status

   a. Professional [ ] b. Civil servant [ ] c. Self employment [ ]

   e. Trading [ ] f. Unemployed/ housewife [ ] g. Artisan/ Tailor/ Hairdresser [ ] h. Others (specify) [ ]

8. Do you receive some income?

   a. Yes [ ]   b. No [ ]

9.Estimate how much you receive daily or weekly……………………………………….

10. How much do you spend/contribute to the spring regularly ……………………………

11. How many people live in your house? …………………………………………

a. males …………….

b. females ………………..

12. What are their age ranges and how many are they?

a. under 5`s	
b. children (6 – 12yrs)	
c. teenagers (13 – 24yrs)	
d. adults (25 – 59yrs)	
e. the elderly (above 60yrs)	

SECTION B

INFORMATION ON EFFECTIVE SPRING UTILIZATION

Optimal Use

13. Does everyone in your house have access to the spring water?

a. Yes ☐ b. No ☐

14. If No, why? ....

15. Can you estimate the distance from the spring to your home (In meters)?

16. How many times do you fetch water from the spring daily? …………………………..

17. Before the rehabilitation of this spring, how long does it take to fetch water from the spring?......

18. After the rehabilitation work, how long does it take to fetch water from the spring? ………….

19. Do you usually have long queues for fetching water from the spring sites?

a. Sometimes ☐ b. Always ☐ c. Never ☐

20. Has the rehabilitation of this spring saved time, hence reducing the length of time spent to fetch water from the spring?

a. Yes ☐ b. No ☐

21. If yes, what do you do with the time that has been saved? …………………………………..

22. What volume of water is been fetched daily in your house?....................................

23. Has the volume of water increased since the rehabilitation of the spring

a. Yes ☐ b. No ☐

24. If yes, what has this increased volume helped to achieve? …………………..

25. What economic/agricultural gains can be attributed to the increase of the volume of water from the springs.

	Yes	No
Farming		
Business (pure water,sale of ice block,grinding machine e.t.c)		
Rearing of livestock		
Better nutrition		
Others (specify)		

26. What do you do with the water?

a. Cooking ☐ b. Drinking ☐ c. Business (pure water and ice block) ☐. Washing ☐ e. Cleaning ☐ f. Others (specify) ☐

Hygienic Use

27. What type of container do you use to fetch water from the spring?

a. Plastic ☐ b. Clay ☐ c. Metal ☐ d. Other (specify) ☐

28. Does the water container used to fetch water from the spring have cover?

a. Yes ☐ b. No ☐

29. What type of water container do you use to store water at home?

a. Plastic ☐ b. Clay ☐ c. Metal ☐ d. Other (specify) ☐

30. Does the water storage container in your home have a cover?

a. Yes ☐ b. No ☐

31. Do you wash these water storage containers?

a. Every day ☐ b. Alternate day ☐ c. Only when dirty ☐

32. Is there a container/ladle used to obtain water from the water storage container at home?

a. Yes ☐ b. No ☐

33. What type of container/ladle do you use to obtain water from these storage containers?...........

34. Do you wash these containers/ladles used to obtain water from the water storage containers?

a. Every day ☐ b. Alternate day ☐ c. Only when dirty ☐

35. Do children have access to these water storage containers?

a. Yes ☐ b. No ☐

36. Do you have water storage containers for cooking/drinking different from other purposes?

a. Yes ☐ b. No ☐

37. Do you have pets/animals (especially chicken and goat).

a. Yes ☐ b. No ☐

38. If yes, do they have access to the water storage container?

a. Yes ☐ b. No ☐

39. Do you give any type of treatment to the water?

a. Sometimes [ ] b. Always [ ] c. Never [ ]

40. What type of treatment do you give?

	Yes	**No**
Boiling		
Filteration		
Addition of alum/ other chemical		
Others (specify)		
None		

41. Has the rehabilitation of this spring improved the hygienic practices and the general cleanliness

of your home?

a. Yes [ ] b. No [ ]

42. Could you explain in what way the hygienic practices has been improved? ………………….

Consistent Use

43. Apart from the spring, which other sources of water do you have in and around the community?

	Yes	No
Stream/river		
Well		
Borehole		
Water vendor		
Rain water		

44. Before the rehabilitation of this spring, which was your preferred source of water?

a. Stream/river ☐ b. Well ☐ c. Borehole ☐

d. Water vendor. ☐ e. Rain water. ☐ f. spring ☐

45. After the rehabilitation of this spring, which is your preferred source of water?

a. Stream/river ☐ b. Well ☐ c. Borehole ☐

d. Water vendor. ☐ e. Rain water. ☐ f. spring ☐

46. Has there been water shortages from this spring at any time of the year?

Season	Yes	No
Rainy		
Dry		

47. How many times do you fetch water from these sources on a daily or weekly basis? …………..

48. If there are other sources of water that you use aside from the spring, do you pour the water from all sources in one (1) storage container?

a. Sometimes ☐ b. Always ☐ c. Never ☐

49. Do you fetch water anytime you go to the spring?

a. Yes ☐ b. No ☐

50. When do you prefer to draw water from the spring?.......................................

51. Why do you prefer your choice in question (50) above?..

52. Which season of the year do you use the spring water mostly?

a. Rainy ☐ b. Dry ☐

SECTION C

INFORMATION ON HEALTH STATUS

53. Before the rehabilitation of this spring, has there been any outbreak of disease which may be due to the use of water?

Disease	**Yes**	**No**
Malaria		
Thypoid		
Skin rashes		
Diarrohea		
Other (specify)		

54. Since after the rehabilitation of this spring, has there been such complaints of those diseases?

a. Yes ☐ b. No ☐

55. What are these diseases and which age range are mostly affected?

	DISEASES (NO. OF EPISODES IN 3 MONTHS)						
	Thypoid	Diarrohea	Dysentry	Cholera	Yellow fever	Skin rashes	Malaria
Under 5`s							
Children (6-12yrs)							
Teenagers (13-24yrs)							
Adults (25-59yrs)							
Elderly (above 60yrs)							
Women							

56. Which persons are mostly affected?

57. When these illness occur, do you seek help?

a. Yes ☐ b. No ☐

58. What prompts you to seek for medical help? ………………………

59. Where do you go to for medical attention?

a. Clinic ☐ b. Hospital ☐ c. Chemist ☐

d. Traditionalist ☐ e. Others (specify) ☐

60. How often do you seek medical attention? …………………………

61. Has there any deaths from these diseases? ………………………………..