RAINWATER HARVESTING TO MEET THE PORTABLE WATER SUPPLY OF RESIDENTIAL BUILDINGS IN TAYI VILLAGE MINNA, NIGER STATE

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KING, Rabiu
MTech/SET/2017/7280

DEPARTMENT OF BUILDING
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

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ABSTRACT

In semi-arid cities such as Tayi-village at Bosso local government area Minna of Niger state, with problems of aridity and a shortage of potable water supply to meet the increasing population, water demand is a major challenge faced by the residential in the studied area. It is against this backdrop that this study is aimed at rainwater harvesting RWH to meet the potable water supply of residents in the study area. The study used quantitative and qualitative methods of data analyses. Direct surveys, observation, rainfall records and water samples were collected from the available rainwater harvested sources in the area. Descriptive statistics; Mean, range, standard deviation and coefficient of variation (CV) were determined. The parameters were tested for any significant difference amongst the sources. The study discovered that rainwater harvest is found to be technically feasible based on the prevailing rainfall pattern. Over 90% of households have a rooftop constructed from technically appropriate materials. Average roof of 80 m^2 will collect 82,835 L/yr (45 L/person/day) for a family of five people, which is near the water demand for drinking and cooking purposes. The study concludes that, physiochemical properties of rainwater were most influenced by the types of harvested source and their component materials. Statistically significant differences were also observed in some physico-chemical quality parameters between corrugated iron roofing sheet and aluminum roofing sheets. The study hereby recommends that due to the type of roofing materials, rainwater should go through proper treatment in order to be used for potable purposes.

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1.0 INTRODUCTION

1.1 Background to the Study

Around the world, groundwater makes a critical contribution to progressive realization of the human right to water. In developing country contexts—where 2.1 billion people still lack access to safely managed water and 844 million lack even basic water (World Health Organisation & United Nations International Children's Emergency Fund, 2017) – development of groundwater is considered a key strategy for addressing gaps in service delivery (Velis *et al.,* 2017) and for building resilience to the impacts of climate change (Howard *et al.,* 2016; Velis *et al.,* 2017). Water scarcity is recognized as an increasing severe problem with global implications. The distribution of water reserves is not homogeneous both geographically and sequentially (Adejuwon, 2012). Lack of water of adequate quality and quantity is a major constraint to development in many areas of the world. It affects every aspect of human life: health, agricultural yields, food security, technical development, and the economy of States. Water scarcity and water quality problems are of particular concern in the tropical regions of the world where many countries are less developed (Nelly, 2010). However, Global water demand will grow significantly over the next two decades in all the three components, industry, domestic and agriculture while available water supply sources are diminishing owing to the population rise, climate change, and pollution, causing a globally acknowledged situation of water scarcity, especially in developing countries (Wheida & Verhoeven, 2007; Fang *et al.,* 2007; World Water Assessment Programme (Nations Unies), 2018).

Rainwater harvesting is not a new concept in water resources management. It has been in existence for a long period of time before the advent of large-scale public water systems. Rainwater harvesting is being encouraged and promoted in China, Brazil, Australia, and India. In New Delhi and Chennai, India, it is mandatory to have a rainwater harvesting system for a building plan in order to secure approval from the local authority (UN- HABITAT, 2015). Rainwater harvesting provide natural soft water which can serve non potable indoor usages. After appropriate treatment, rainwater provides safe water for human consumption. In addition to its potential to generate considerable quantities of water, rainwater results in collection of decentralized water which makes it less expensive when compared with well drilling and water supply from the public taps. Rainwater can also be used to minimize water loss and to augment water supply in any watershed systems (Mwenge-Kahinda *et al.*, 2010).

Tayi village is one of the communities within Minna urban area with a population that is steadily growing. The demand of water for drinking and sanitation purposes increases proportionally with population growth. Among the more serious problems in Tayi village is lack of adequate and safe water supply. Scarcity of water begin in Tayi village from January to June (Dry Season), from July to December the major sources of water in the area is rain water directly or indirectly. These problems could be mitigated with an adequate water supply, combined with policy changes and proper education. Rainwater harvesting can possibly be one of the solutions for the most vulnerable segment of society in terms of water supply. Rainwater harvesting is an appropriate technology for Tayi village despite the fact that rain is not well distributed in the city overtime. When rain is adequately harvested, it can be sufficient to fulfill the needs of households during critical period of dry season. A storage tank with the capacity to hold 16,000 liters can provide good complementary supply to other available water sources for the consumption of a family with five individuals during a period of 10- 12 months (Branco *et al.*, 2015). The availability of water through a tank also relief women and children from walking long distances to fetch water. Furthermore, access to harvested rainwater protects the family members against illnesses related to waterborne diseases through consumption of contaminated surface water.

1.2 Statement of the Research Problem

Water, like any other commodity of necessity, is demanded from different sources (Yisa & Jimoh, 2010). It is a quiet virtuous in several countries. Water supply in Nigeria is a civic virtuous with no marginal cost, and its availability pattern has divided society into numerous categories based on accessibility standards. Scarce resources on the part of the government to meet the infrastructural demand in ensuring equitable provision of water supply have been inadequate (Stanley, 2017). In spite of various laudable policies being put in place by the successive governments to ensure that access to adequate portable water supply is made possible, the problem of inequality of water infrastructural provision remain unsolved. However, the rate at which infrastructural services like provision of water is being provided is grossly inadequate in meeting the population demand.

Tayi village is a sedimentary complex rock which have different capacity of retaining water all year round. During the rainy season, the study area's wells were flooded, but when the dry season arrived, all of the wells dried out. This makes it difficult to get a sufficient amount of water. With the increase in population, the situation of scrambling for domestic water is aggrevated. Lack of access to pipe borne water is an increasing problem of the area, where the vendors tend to take advantage of the situation and sell 20 litres at 50 Naira in dry season. Shallow aquifers are contaminated by the abbatoir activities located in the region. Such problems are considered to be significant barriers to improving community health and reducing poverty. Part of the problem also include households demand for water from different sources with no regard for its quality.

Demand level and the quantity of the sources are being currently polluted as a result of natural and human interference. Adoption of various rain water harvesting techniques needs to be evaluated in Tayi village. This is because variability are expected to affect water availability as well as the methods of water harvesting which needs to be quantified. Thus, the need to guarantee rainwater harvest to meet water supply level to matched demand levels as well as sustainability of good quality of water supply form the main thrust of this study.

1.3 Aim and Objectives of the Study

The aim of this study is rainwater harvesting to meet the potable water supply of residential buildings in Tayi Village with a view to utilizing as potable water for the environment. The specific objectives of the study are:

i. Examine the rainfall pattern in Tayi village.
ii. Evaluate the supply and demand variation of water for potable use.
iii. Evaluate the quality of rainwater harvested from corrugated iron roofing sheet
iv. Ascertain the impacts of roofing sheets on harvested rainwater quality.

1.4 Research Questions

The present study intends to address the following research questions:

1) How is the rainfall pattern in Tayi village?
2) What is the requirement of supply and demand of water for potable use?
3) What is the quality of rainwater harvested from corrugated iron roofing sheet and aluminum roofing sheets?
4) What are the impacts of roofing sheets on harvested rainwater quality?

1.5 Scope of the Study

The focus of this study is on the situation of demand, supply and quality of water during water deficit periods, water security, water quality, among other context such as water resource management, clean water and considering the importance of water in human life. The study is restricted to Tayi village, it will assess the practice of rainwater harvesting techniques and evaluate the quality of the harvested rainwater from the sources of harvesting in order to understanding the contextual magnitude of disparity existing in water demand during water scarcity period in relation to the supply situation vis-à-vis water quality.

1.6 Justification for the Study

Water harvesting techniques in urban area are crucial for both economic and social activities that can improve living standards. The benefits of water harvesting include securing and increasing crop production in semi-arid regions where rainfall is insufficient, control of soil erosion and land degradation. This is in addition to serving as an adaptation strategy to climate change. Past experiences show that rainwater harvesting is an innovative approach for the integrated water resources management and sustainable development (Stanley, 2017). Evaluation of appropriate water harvesting techniques is necessary to identify factors that affecting the techniques most used and give recommendations on their improvements. Understanding the effects of climate change on water availability will assist in decision making regarding appropriate intervention of water harvesting techniques. Water harvesting techniques in Tayi village will eventually contribute to sustainable livelihood and poverty reduction. Residents ‟ awareness of climate change impact will effectively support and help more to evaluate as well as find out the impact of the climate change and variability on water resource utilization, coping, and adaptation strategies.

In Nigeria, series of existing research (Fang *et al*., 2007; Nelly, 2010; Stanley, 2017) on assessment of water demand and supply have been on proffering solutions to the challenges facing the country on domestic water supply and demand have tried to compare two seasons of the year (wet and dry seasons). This study is to complement other studies in the area of water demand, supply and quality situation as recommended by World Health Organization and SON (2017) in Niger State. It tried to consider the situation of water supplied and demand alongside its quality during the deficit period when there is no alternative or supplement from the rain. This is because the problem of unsafe water sources has become a major socio-economic concern that requires an integrated scientific research method, and to be able to create an avenue for policy makers to devise empirical solution to the challenges of domestic water sources in Niger State of which this study will be appropriate. Optimization of water usage and the conservation of water as a natural resource can help to overcome water shortage.

1.7 Study Area

Tayi village is located in the eastern part of Minna the capital of Niger State. The study area lies between Longitude 6° 29^1 and 6° 35^1 East and Latitude 9° 33^1 and 9° 40^1 North. At the North-east corridor of the town lies continuous steep outcrop of granite, which form a limitation towards physical development in that axis. In the present political zoning system, the village is within the North Central Zone, and occupies an area of about 884 hectares. It is about 145 kilometers by road from Abuja, the Federal Capital of Nigeria. Since 1999, Tayi village has experienced change in both pace of growth and types of space occupied for development. It has a total area of 74,344 km2 wide (Sanusi, 2011). As shown in Figure 1.1.

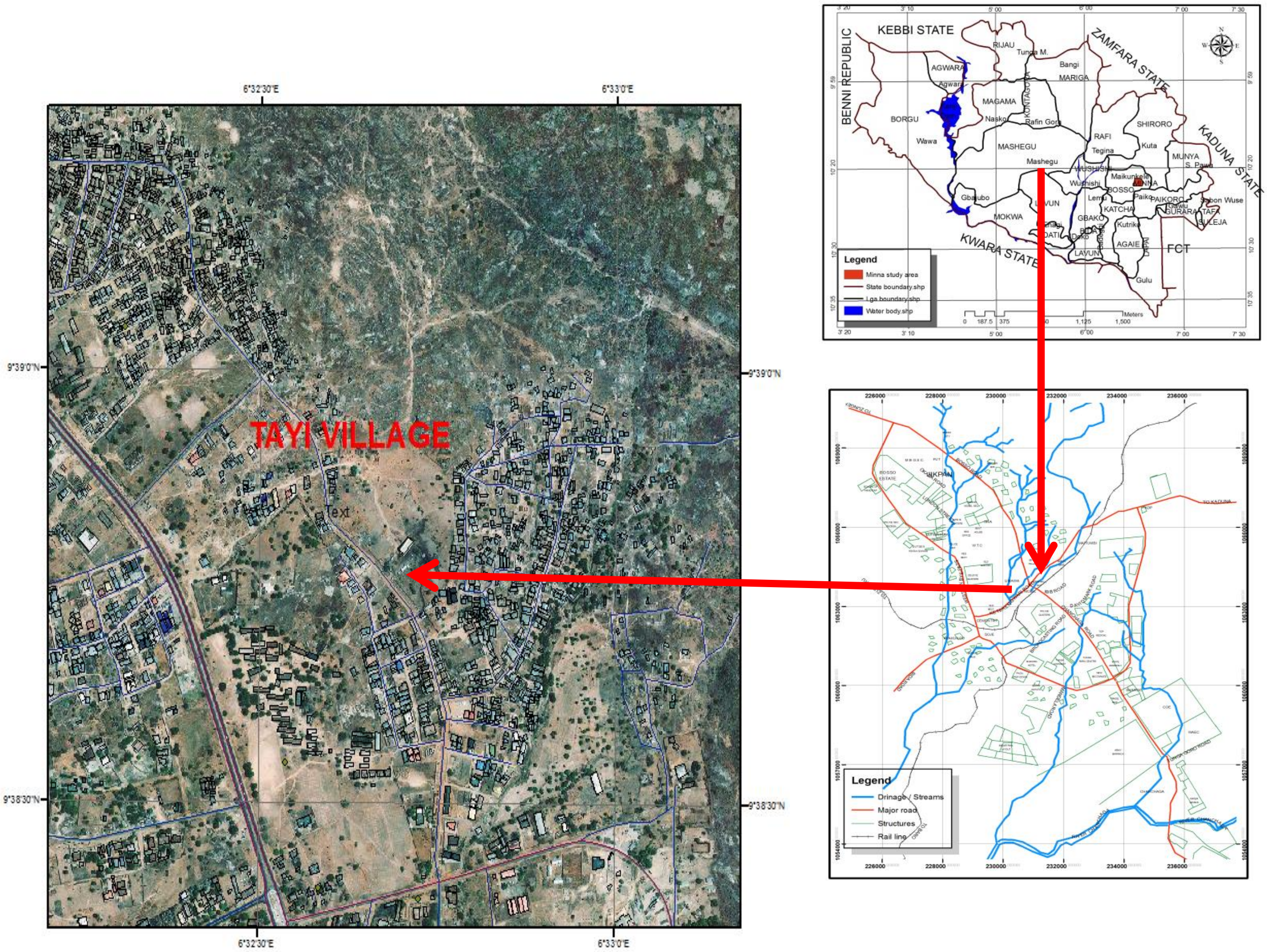

Figure 1.1: Location of Tayi Village in Minna, Niger State, Nigeria

Source: Niger State Ministry of Land and Housing, (2021)

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Water

Water is a common chemical substance that is essential for the survival of all forms of life in typical usage (Smith *et al.*, 2016). Initially water refers to only its liquid form or state, but the substance also has a solid state, ice, and gaseous state, water vapor or steam (Stanley, 2017). Water according to a famous Greek philosopher, ponder of the fifth century B.C. is the best of all things, covering over 70% of the earth's total landmarks but it is limited in quality and quantity. Water is used by man for a variety of purposes, among them irrigation, navigation, hydro-electric power generation domestic and industrial. The most fundamental use of all is communities' water supply for immediate and vital needs that is washing, cooking and sanitation (Biswas, 2014). The supply of adequate and notable water is important to the general welfare and productivity of a population. Seventy percent (70%) of human body functions depend on water and people begin to feel thirsty after a loss of only one percent (1%) body fluid and risk death if fluid loss nears ten percent (10%) (Gleick, 2016).

Water, in the words of Jovanovic, (2017) is both a consumption and investment good. It is an investment good in that it is part of local infrastructure and can indirectly generate additional future economic activity by attracting and assisting local commerce and industry. This commodity cannot therefore be replaced by any other substance. Due to this, it is of high demand by man and the demand tends to be perfectly inelastic. Water resources development, through which water as a resource is explored and exploited to make it portable and economically accessible source to satisfy human need is mostly treated as social goods consumed mainly by households, industries and institutions in most developing countries (World Bank (2010a). It is the most sought after social good and ranks very high in the developmental preferences in most communities in developing countries (Emoabino and Alayande, 2016). According to Gleick (2016), an overall basic water requirement of 50 litres of water per person per day is a minimum standard to meet four basic needs (drinking, sanitation, bathing, and cooking). Freshwater demand per capita is rising substantially as communities develop economically. Low household water uses in developing communities today reflects difficulty in obtaining freshwater.

2.1.1 Demand for water

Water demand indicates both current and/or expected water consumption in any given area over a specific period of time (Vivek *et al.,* 2010), although demand for water is used inconsistently. According to Waziri *et al.,* (2013), it is sometimes referred to as water withdrawal and at times to water consumption or depletion**.** Demand for water is a strategy of meeting human benefits through conservation and a dramatic increase in water use. The concept of water demand includes all defined facilities at the basin scale. It is classified as irrigation demand and non-irrigation demand of which the later is further disaggregated into domestic, industrial, recreational and livestock water demand. The amount of water that people use does not depend only on minimum needs and how much water is available for use but on the level of economic development and extent of urbanization shouldering around democratic advancement. Withdrawals of water have grown tremendously in meeting the rising industrial demand, rising domestic demand and increasing reliance on irrigation to produce food (Welderufael *et al.,* 2011). According to Vivek *et al.,* (2010), Demand control policies, however, require that water supply agencies establish complete, accurate, and representative information about current water consumption patterns. A realistic assessment of regional water consumption is essential in understanding how water suppliers can accommodate variations in time and type of use. Consumption patterns include a number of water use characteristics representative of the individual users in space and time.

These characteristics include, but are not limited to the number of inhabitants to be supplied with water and their demographics, the consumption habits of the population, the type of development, property size; and property landscape. Each of these (and several other) parameters play a role in explaining overall demand. However, data limitation has precluded analysis of the effects that these variables play. Municipalities have relied upon analysis of large-scale consumption patterns to evaluate management options (Gracia *et al.,* 2003; Forster, 2015).

Water crisis has become a major concern both among different users and regions in a state, country and also across international borders. In most communities in Nigeria at large, several public water management parastatals exist and have been in operation for several years, but scarcely any is performing efficiently. Most urban centres lack effective public water systems that could ensure regular supplies to the demand of the community. The output from the few available systems only meet a small percentage of the water need in the cities (Baguma *et al.,* 2010; Woltersdorf, *et al.,* 2015), and most new extended lay-out areas in many cities hardly have any water pipe network connection (Sanni, 2002) till recent there is still no any difference in meeting water demand despite the setting of millennium goals on adequate water supply by the year 2000. In an attempt to supplement the inadequacy arising from the failure of public water systems at meeting the soaring need of the populace, alternative sources are often sought which include, rain harvesting, wells, surface water from rivers and ponds. In recent years many international organizations such as United Nations, World Bank, Asian Development Bank, the Inter-American Development Bank have become heavily involved and interested in water policy, supply and use (Ajibade, 2010; Biazin *et al.*, 2012). They embark on various water projects ranging from United Nation International Children Education Fund (UNICEF), Local Empowerment and Environmental Management Projects (LEEMP), Federal Government of Nigeria- European Economic Commission – Middle Belt Programme (FGN-EEC-MBP) and the lower Niger River Basin Development Authority (LNRBDA) to most recently the drilling of boreholes and construction of water tanks (Ajibade, 2010). Prominent among these is the recent Local Empowerment and Environmental Management Projects (LEEMP) which embark on drilling of boreholes, wells and construction of roads in the rural and medium-sized towns.

2.1.2 Water supply

According to Oyebode (2019), supply of water on commercial bases has existed for several decades, it is usually given attention when there is major breakdown in public water supply system. The tempo of water supply increased with the preparation for and campaign in favor of the United Nation’s International Drinking Water Supply and Sanitation Decade (1981 – 1990). The goal of this programme was to provide water for all by the year 1990 at 120 litres/day per person for domestic use (Oyebode, 2010). However, just before the commencement of this programme, only 22% of the rural and 55% of urban population enjoyed potable water (Leton, 2017). These figures have increased only marginally. In absolute terms, by 1986 each rural dweller in Niger State had access to 25 litres of potable water per day while urban counterpart had access to 60 litres/day (Muhammadu, 2014). The Niger State Rural Water Supply and Sanitation (NSRUWATSAN) Project was established in 1987 after signing a Memorandum of Understanding (MOU) between UNICEF on one side and Federal and State governments on the other side precisely on 8th, July 1987. This was to make Niger State to be among the top three Rural Water Supply and Sanitation Agency in Nigeria (RUWATSAN) in terms of provision of potable ground water, safe sanitation and effective hygiene promotion to the rural communities by the year 2020. The method by which portable water was delivered to the consumers were organized in the form of hand dugged wells, canals, aqueducts, boreholes, reservoirs and distributing pipe-built through community efforts to provide central supplies daily. The households collect water from these sources in gourds, jars, water pots, or vessels, and some through piped lines. The use of water in these communities is categorized into secondary and primary methods (Water Aid, 2016).

According to Oyebode (2019), supply is the availability of substance or resources to sustain the desired needs. In another way McDonald *et al.,* (2016) considered water supply as the provision of water for drinking, domestic use and irrigation. The availability of this resource is controlled by hydrological cycle (Stanley, 2017) and could be found from fossil and active groundwater as well as riverine abstraction. Domestic water supply varies from very large urban systems serving large population to small community system. Communities manage drinking water system with both piped and non-piped distribution commonly used in developed and undeveloped countries (WHO, 2008). Water vendors supplying water by transporting water to households or at collection points are common in many parts of the world where scarcity of water limit access to suitable quantities and quality of drinking water. They use a range of modes of transport to carry water for sale directly to the consumer, including tanker trucks and wheel barrows/trolleys. Municipal water managers today are attempting to understand better the general patterns associated to water use in the supply region. Most population whose water is derived from household sources such as private wells, boreholes and rainwater, need appropriate effort to ensure safe collection, storage and perhaps treatment of their drinking water (Biswas & Mandal, 2014).

According to Mohammed *et al.* (2013) most of the communities in Niger State water supply had been deteriorated since 1980s. Most towns depend on traditional shallow wells, river beds which dry up during dry season and yield highly colored and muddy water. Due to high demand for water in these communities, the water is never enough to satisfy their demand. In Lavun, Bida, Mokwa and Edati Local government areas, Kutigi and Mokwa districts appear to be the hardest hit (Olasehinde, 2010; Mohammed, *et al.,* 2013). Edati local government is in watershed area that is very close to rivers Niger and Kaduna. Although Bida town had once enjoyed water scheme project but now the city is seriously hit with scarcity of water supply. Those towns that are close to perennial rivers like the Niger, Kaduna, Gurara, Manyara Rivers, they are faced with the problem of obtaining portable water as the rivers are heavily polluted by wastes of all kinds. Moreover, some inhabitants have to travels very long distances in search of water from dug out ponds especially during the dry season. Communities that are still faced with serious water shortage including Suleja and Minna municipal area during the dry season. Some of these communities depend on the easily dried unprotected traditional wells dug out ponds and springs.

As a province in defunct North Western State, most of those towns now Local government headquarters were of very remote settlements and only few public wells were at that time serving as the main sources of water, most of which are presently abandoned because of inadequate quantity of water to meet the communities domestic needs (Mohammed *et al.,* 2013). In order to provide adequate potable water supply to some prominent towns like Suleja, Minna and Bida in 1987 Niger State government went into signing a memorandum of understanding with UNICEF and Federal government (Mohammed *et al.*, 2013). A project sponsored by World Bank to provide potable water and safe sanitation by promoting effective hygiene to the rural communities in Nigeria by the year 2020. No sooner after commissioning these projects in 1995, the capacity of the dams built in towns like Bida, Minna and Suleja became inadequate in serving these communities. Recently, the state government went into collaboration with World bank to provide potable water through bore holes which were handled by Local Environmental Empowerment and Monitoring project (LEEMP), but still yet the government of Niger State is disturbed over the situation of shortage of water supply in the entire state after spending much money in trying to ensure adequate water supply in the state with very little result. For instance out of 53 boreholes in Kutigi Local government only 37 (70%) were successful while in Kontagora Local government only 77(74%) out of 104 boreholes were successful, Magama and Rafi Local governments out of 66 and 56 boreholes only 42 (63.6%) and 33(58.9%) were respectively successful. Most State water boards and the Bi-water projects in the Local government headquarters had long been abandoned for lack of maintenance. The state government had been worried about the situation of water supply and demand.

Biswas and Mandal (2004) use a software package called Mocasim II to perform a stochastic analysis on water supply systems. This allows the relationship between the reliability of the supply system and the capacity of its service reservoir(s) to be quantified using Monte Carto analysis. The capabilities of Mocasim II include the determination of probability distributions for network properties such as flow rate, pressure and water quality at any node in the network.

2.1.3 Water quality

Water quality is a technical term that is based upon the characteristics of water in relation to guideline values of what is suitable for human consumption and for all usual domestic purposes including personal hygiene, which consist of microbiological, chemical, and physical aspects. According to Aladenola and Adeboye (2010), water is purified or treated to get rid of harmful substances or reduce them to the minimum permissible limit to make them safe and fit for human consumption or suitable for intended general domestic uses. Dahunsi *et al.* (2014) once explained that presence of organic substance in water results to contamination, thereby rendering the water to lose its quality. According to Dobrowsky *et al.* (2014), the appearance, taste or odor of well water or other source offers some information on obvious contamination, but chemical analysis is needed to detect most contamination in water. Hence domestic water needs to be treated in order to make the water safe for human consumption. Ali (2012) observed that the consequences of consuming water directly without treatment could be detrimental to the health, as it may result in possible neurological damage to foetus, and other complication in children less than three years of age and even abortion in pregnant women.

In microbial aspect, drinking water is expected not to contain micro-organism that are known to be pathogenic or bacteria that would indicate excremental pollution. In biological aspect, water quality is not to have parasite protozoa and helminthes. When such is introduced into water through human or animal faeces, the water is therefore rendered polluted. Hence, when water loses its quality, it is no longer fit to be used for domestic purposes (Glieck, 2016). While in chemical aspects, if any toxic chemical is introduced into the drinking water it can cause either acute or chronic health effects as observed by (Amado & Barroso, 2013). The turbidity, color, taste and odor of water affect the physical aspect of water quality. The turbidity of water is required to be low, because high turbidity inhibits effect of disinfection against microorganisms and enables bacterial growth. In this regard, drinking water is expected to be colorless, tasteless and without odor. In other words, bacteriological tests are used to determine bacteriological safety of water for human consumption and chemical tests tries to identify impurities and other dissolved substances that affect water use for domestic purposes. Water is noted to decrease in being palatable when the amount of minerals dissolved salts exceeds 500 to 1000 ppm which Dobrowsky *et al.* (2014), identified to depend on the nature of minerals (Stanley, 2017).

Land use pattern has profound effect on the physical and chemical properties of water in the basin. For example, Aladenola (2010) and Akinyemi *et al.* (2013) identified the different urban use patterns as a great factor to river pollution. For instance, in pre-industrial revolution times, sewage from the households and industries were dumped into rivers from adjoining communities thereby leading to the deterioration in water quality. Effluents from such sewage, when introduced into the water body, results in drastic change in the quality of the river water.

Heavy metals such as uranium and plutonium are pollutants when end up in stream water led to changes on ecological relationship of aquatic plants and animals as well as man (Alqadami *et al.,* 2017a). Akinsanola and Ogunjobi (2014), Awual *et al.* (2016) and Alqadami *et al.,* (2017a), affirm that such effluents cause’s biological changes in the stream water by encouraging the proliferation of certain bacteria which attribute to health hazards when consumed or have physical contact with polluted or utility water. Alabi *et al.*(2014) observed that acid rain, which results from the reaction between moisture and chemical compounds produces nitric and sulphuric acids fall along with rain to the earth pollutes the lakes, streams as well as ground water and led to the destruction of ecological communities and endangering of human life.

Underground water which serves as the major source of water to many communities through boreholes and wells are often contaminated through contact with unconsolidated sedimentary strata that are composed of fossils and areas of landfill deposit of waste products. Toxic organic substances found underground decomposes into the soil water which are collected through wells and bore-holes drilled to meet the demand for community water supply (Adewale *et al.,* 2015). Marks *et al.* (2013) observed that waste resulting from treatment operations is usually discharged into surface waters which cause the buildup of sludge deposits in streams and landfilled soil strata. This effect of sludge effluent has a characteristics like dissolve oxygen (DO), nitrates and suspended solids on the environment. Lockwood and Smith (2011), sludge effluent are characteristics of substances in raw water which include microorganisms like bacteria algae, fungi and protozoa which also contain suspended and settle solids, organic and inorganic chemicals as well as trace metals, coagulant (usually aluminum hydroxide), polymers, clay, lime powdered activated carbon and other materials. According to Kwaadsteniet *et al.* (2013), the removal of particulate matter is the most important goal of water treatment.

Although in most medium sized towns, it is very difficult to have water regularly with an Escherichia Coli count of 0 colonies per 100 ml, so Majuru *et al.*, 2011) suggested a criteria for bacterialogical analysis of drinking water from unchlorinated sources like streams and uncovered wells. This suggestion was duly considered by WHO, SON and FEPA when presenting the desirable level of Escherichia coli count in water quality (Okoye, 2015).

2.1.4 Water crisis

A major environmental problem that has faced the nation, especially the urban and sub urban centers is the problem of water crisis. According to Chukwu (2015) and Ezenwaji

(2016), pressures of urbanization are becoming more diverse, and increasingly desperate special-interest demand for water is creeping up. In recent decades there has been great increase in growing population resulting into general demand for volumes of industrial, commercial and construction activities. These led to new consumption styles of the dwellers, thereby generating volumes of diversified demand for water (Adeoye *et al.*, 2013).

2.1.5 Water harvesting techniques

Different types of rainwater harvesting management systems have been implemented throughout Kenya as a strategy to secure water resources in rural areas (Wachira, 2015). The selling point for rainwater harvesting is that the methods are simple enough to orchestrate and maintain at individual or community level with little training from specialists or technicians.

Many reports have been written on the potential benefits of rainwater harvesting for rural communities (Olaoye & Olaniyan, 2012; Opare, 2012). Nevertheless, there are few studies (Aladenola and Adeboye, 2010; Oke & Oyebola, 2015; Stanley, 2017) describing the detailed effects of the schemes on water availability, demands, and vulnerability in the case of climatic variations – especially in the light of future climate change. Further studies are a vital part of reviewing the findings from previously conducted water schemes as well as making future rainwater harvesting methods more efficient. RWH systems can be classified by the runoff generating process, the size of a catchment and the type of storage. Runoff generating processes are rivers, lakes and rainfall. The storage type could be storage within a soil profile, a tank or a reservoir and the size or scale of the system determines whether it is regarded a micro or macro scheme (Staley, 2017). There are three main categories of RWH that have been devised and perfected over the years. Each category has its own methods and techniques that are employed to get the maximum amount of profit from each water source, be it floodwater, rainfall or groundwater. The three main forms of WH include Rainwater Harvesting (RWH), Floodwater Harvesting (FWH) and Groundwater Harvesting (GWH).

2.1.5.1 *Rainwater harvesting (Nigeria experience)*

Public water supply in Nigeria started in the early twentieth century with only a few towns managed at the lowest administrative level. Among the early beneficiaries were Lagos, Calabar, Kano, Ibadan, Abeokuta, Ijebu Ode and Enugu. The scheme was maintained with revenue from water sales with virtually no operational subvention from government. Today, all the 36 states and Federal capital Territory in Nigeria have water boards/corporations or public utilities board managing their public water supply. Their efforts are supplemented in many cases, by local governments who supply water to small villages in their areas of jurisdiction. The Federal Government got involved in the management of water resources in 1976 when the Federal Ministry of Water Resources (FMWR) and the 11 river Basins Development Authorities (RBDAs) were created. The purpose of the (RBDAs) was to provide bulk water primarily for irrigation (Staley, 2017).

Following the adoption of the National Water Supply and Sanitation policy in January 2000, the Nigeria Government considered the Federal, State and Local governments. However, the public sector has not been successful in meeting more than a small portion of the residential and commercial demand for water. Services are in critically short supply. Thus, out of the 85 million people living in urban and semi- urban areas less than half have reasonable access to reliable water supply (FMWR, 2000). The process of water supply in Nigeria has now been focused on construction and installation of hand pump boreholes due to their perceived low cost, simple technology which can be operated, maintained and financed by poor rural household (Shittu *et al.,* 2010). However, these hand pump operated boreholes have not been able to meet the increasing water demand and are susceptible to frequent breakdown. A renewed interest in rainwater harvesting has emerged as a result of escalating environmental economic costs of providing water by centralized water system or by well drilling.

2.1.5.2 *Rainwater harvesting infrastructure and urban development*

It is an agreeable fact that stand alone centralized water supply and drainage systems are inefficient as they do not take full advantage of urban storm water resources (Faram *et al.,* 2010; Słyś & Stec *et al.,* 2014). Also satisfying water needs in urban areas with high impervious surfaces and centralized storm water drainage infrastructure like Ijebu Ode lead to rainwater quickly turns from valuable resources into a societal cost in the form of flooding, stream erosion, aquatic habitat destruction and toxic loading on receiving environments. Existing literature on urban rainwater harvesting has largely focused on quantifying the benefits and costs in a developed country context. Specifically, research has been concerned with benefits and costs related to water quality and water quality management outcomes from a water supply perspective (Sojobi *et al.,* 2014). If rainwater harvesting is perceived exclusively as a substitute technology for conventional fresh water management, its potential to promote sustainable behaviours and attitudes is diminished. Thus there is need to see rainwater harvesting as a substantial field that its technology needs upgrade to satisfy developing and developed nations technological needs.

2.1.5.3 *Socio- cultural interpretation of rainwater harvesting*

There has been little research into socio- cultural changes associated with rainwater harvesting. This happens to be an area this paper is focussing; perhaps there exist with this case study context cultural attachment which is capable of preventing utilization of rainwater. Researchers such as Tadesse, *et al.,* (2013) reviewed a wide range of literature associated with social acceptance of general water management regimes and found a predominance of stated preference methodologies leading to a knowledge gap of actual behaviours. Souza and Ghisi (2012) interviewed residents with water harvesting structure in Barcelona wherein they documented differences in social knowledge accumulation between single family and multifamily residential properties. A broad survey of U.K residents by Howard *et al.* (2016) found most respondents having limited experience with rainwater harvesting, but stated positive preference toward rainwater harvesting at an individual property scale and under estimated maintenance requirements.

Another perspective is that integrated water management (which includes rainwater harvesting) is economically efficient from a societal view point because of non-market values and an inefficient distribution of costs and benefits (Vesely *et al.*, 2005; Kettle, 2009; Wilson *et al.*, 2010; Fernandes, 2015). Non- market benefits associated with investment in integrated water management infrastructure, such as innovation, adaptation capacity and skill development are not manifest in the provision of centralized pipe systems. Furthermore, the societal costs of ecological damage (present and future) are not included in municipal water prices, which are based on the cost of abstraction, treatment and distribution. These costs are either paid by society through public expenditure or passed on to future generations.

2.1.5.4 *Domestic roof water harvesting*

The term domestic roof water harvesting describes a broad range of techniques which collect rainfall run off for different end- users by linking a runoff producing area with a separate runoff receiving area. The rainwater can be collected and stored from roof tops, land surfaces or rock catchments. There are different types of domestic roof water harvesting exist and will subsequently be referred to opportunist domestic roof water harvesting where no permanent equipments is employed, Informal domestic roof water harvesting where minimal but permanent storage is employed and Formal domestic roof water harvesting where at least 400liters storage tank is installed (Forster *et al.*, 2015).

Where piped water is laid households, rainwater tanks are not likely to be considered but where water is distributed via public standpipes; tanks can offer advantages in terms of convenience and individual control. Rainwater can be collected in vessels at the edge of the roof which is the very basic form of this technology. Many households with a hard roof perform opportunist and informal domestic roof water harvesting. When it rains, the people who practice opportunist domestic roof water harvesting use whatever containers they have at hand to collect run off. The yield exceeds 40liters on a typical rainy day due to the absence of proper guttering and the limited water storage facilities (Thomas *et al.*, 2014). The roofs with corrugated iron (aluminum) provide ideal conditions for domestic roof water harvesting to be performed. Where informal domestic roof water harvesting is implemented the guttering, means of storage and of subsequent water abstraction is not very satisfactory.

2.1.5.5 *Rainwater harvesting for flood control*

Rainwater harvesting can be done to recharge the local groundwater aquifer by directing the rainwater into natural systems such as swales and bioretention structures that have the capacity to reduce the velocity of the water and infiltrating the water into the ground (Daigger, 2011). As far as domestic use is concerned, the system for harvesting rainwater is relatively easy and cheap to construct. It involves the utilization of rainwater harvesting systems such as gutters, running along roof- eaves to collect rainwater and thereafter directing the water to a covered reservoir for later use.

Untreated harvested water from reservoir serves sanitary needs for toilet flushing for instance, as well as for laundry, gardening and car washing. Rainwater can also be treated with local methods such as filtration and chlorination to make it potable. Household harvesting systems are appropriate in areas with an average rainfall greater than 200mm per year (Ikhile and Aifesehi, 2011), and could be used in any region of the country. In an estate install harvesting system with no running cost, although they would be responsible for ensuring that roof gutters are cleaned out occasionally to prevent the accumulation of waste rising from bird faeces for instance. Rainwater harvesting can be utilized as an alternative water supply system to be utilized in periods of down-time in local settlement (Alabi, *et al.,* 2014).

2.2 Theoretical Framework

Theories are important in studies involving economic growth, planning, prediction and development in various ways. Sound theories influence the development of strategies that are usually adopted. They also help in identifying the crucial variables that needed for prediction and development for the planners and policy makers. Most importantly, such theories are crucial to the researchers because they help them in formulating hypotheses for investigation and verification (Obeta, 2018).

In view of its importance, the study review some relevant theories on water demand and supply, analyze their limitation and implications if adopted for planning purposes. One of them referred to as the water requirement approach, tries to project for future residential water demand based on past consumption data. The requirement approach is computed by multiplying per capital water consumption by projections in population (Bower, 1966). Some workers in Nigeria have employed this theory (Ali, 2012; Babic *et al.*, 2014). But the theory for water demand as a forecasting tool has attracted a number of criticisms from researchers. For instance, Adeoye *et al.*, (2013) noted that the assumption of population and per capita water consumption determines the quantity of water demand for the future seems to blanket some other important factors like price, consumers income and physical and economic variables that affect water demand and consumption patterns.

Another intellectually challenging and more approximate to reality is the component approach. Here attempts are made to understand why water demand fluctuates over time (Ayoola *et al.*, 2014). Factors that are likely to influence water demand are identified and measured, and their likely effect on the future changes are assessed. The major assumption is that future changes in each component are predicted separately and aggregated. This technique has high relevance and is often employed.

2.2.2 Equilibrium approach in regional water management

The objective of equilibrium approach is to develop an iterative algorithm for determining an optimal water supplies and demand in a network assuming each significant supply and demand unit can be represented by a model. According to Guariso (2017), to determining an optimal solution in water management, a certain flow is to be transferred from a supply to a demand, the cost of delivering the final unit of water must be equal to the benefit generated by the final unit or marginal benefit. Among other models this had been put forward in this study, because Guariso (2017) focus was on the modality of reaching an equilibrium through two functions $Q^D (P)$ (quantity of demand Q per price p) and $Q^S (P)$ (quantity of supply Q per price p) which this study tries to portray.

In applying a market equilibrium approach therefore to regional water management, water supply and demand are not independent of one another, as usually assumed in market equilibrium analysis. For example upstream users affect downstream users;

ground water withdrawals deplete surface waters. Irrigation demand models were formulated to yield the total volume needed in the whole growing season rather than some critical peak flow, so the assumption in the present analysis of a constant average flow is consistent with the output of these models. The benefits B of a demand unit is in general a function of the amount Q of water consumed (Guariso, 2017) Figure 2.1.

$$B = B\ (\mathrm{Q}) \tag{i}$$

If the water is paid for a price p, the profit of the unit is $[B\ (\mathrm{Q}) - p\mathrm{Q}]$ so that a particular amount of water will be demanded for each given price. Under this assumption the unit is profit maximizing. This amount of water can easily be determined by solving the following optimization problem.

$$\underline{\mathrm{Max}}\ [B\ (Q) - p\ Q] \tag{ii}$$

$$Q = Q^{\mathrm{D}}\ (p) \tag{iii}$$

If problem (i) is solved for all values of the parameter p, a function, called demand function is obtained which gives the amount of water demanded by the units as a function of the price of the water. If there are no explicit inequality constraints added to problem (i), the necessary conditions for optimality imply $d/\,dQ\ B\ (Q) = P$

Demand (Q^D) and supply (Q^S) functions and equilibrium solution E

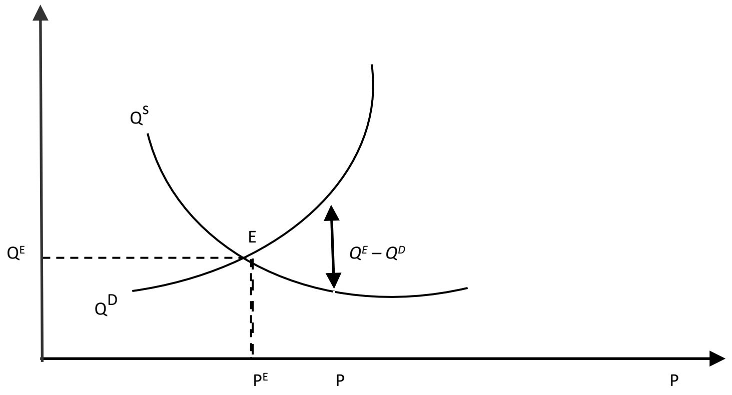

Figure. 2.1: Demand, supply and equilibrium

So that the demands function (ii) can be interpreted as the marginal benefit of the unit, inverse of the above function.

A consideration can be applied to supply of a reservoir or a pumping station at cost $C(Q)$ supplies an amount Q of water and sells it at a price P. In this case the optimization problem solved by the unit is Max $[pQ - C(Q)]$

And the corresponding solution gives a supply function

$$Q = Q^S(p) \qquad \text{(iv)}$$

This is just the inverse of the marginal cost of supply.

The benefit and cost functions $B(Q)$ and $C(Q)$ and the demand and supply functions $Q^D(P)$ and $Q^S(p)$ may be themselves the result of complex optimization procedures and for this reason they may not be explicitly known.

When the supply and a demand unit are connected, the value of water exchanged can simply be obtained from the plot of figure 2.1. The point E in the graph called the equilibrium point is characterized by $Q^S(p_E) = Q^D(p_E)$

And gives the value QE of the flow which must be exchanged between the two units in order to maximize the total net benefit of the system

$$\text{i.e. } \underset{Q}{\underline{\text{Max}}}\ B(Q) - C(Q)] \qquad \text{(v)}$$

The equilibrium price PE is the price which put the supply and demand units to both amount of water and the selected value namely Q^E that maximizes the total net benefit of the system. If the two functions $Q^D(P)$ and $Q^S(P)$ are given, the equilibrium solution is immediately obtained, but if on the contrary, only the models for computing Q^D and Q^S are available, it becomes important to obtain the equilibrium solution. One way of doing this consist of fixing a price P and computing the corresponding imbalance Q^S-Q^D

and then iterating on the price until the imbalance is zero. This model can be adopted in carrying out water supply from one source to the area of demand effectively. The contrary is that equilibrium in water supply and demand is difficult to reach because of the rapid growth of population.

2.3 Review of Related Literature

Various ideas and perception have been put forward by many researchers on water supply and demand situation in different parts of the world. The relevant literature are reviewed and presented in this section. Obviously there are existing information for both global and regional water development and management, which increases the complexity of physical aspects of water resources development and introduces other economic, legal, social and political intricacies. According to World Bank Report (2010a), about 1.2 billion people in about 20 developing countries have no access to safe water. Kaur and Gupta (2015) projected that by the year 2020 the number of the countries will increase to 30 out of which 21 countries will be in low income, food deficit nations. Based on this, it is seen that even at global level, water withdrawals are expected to increase by 35% by the year 2020. The per capital water availability has greatly declined by approximately 40% in Asia and by 50% in Africa (Dobrowsky, *et al.,* 2014). This holds as Niger State government try to combat water scarcity by collaborating with international bodies like World Bank in providing Water to the people through LEEMP. All these are efforts in meeting water supply satisfaction before 2020.

2.3.1 Global water supply strategies

Water is vital for domestic, agriculture, manufacturing, transportation, and countless other human activities (Glieck, 2016). Water plays a key role in sculpturing the earth’s surface, moderating climate and diluting pollutants. In western United States irrigation account for 85% of all water use and much of this water is used ineffectively. One reason for this is that Federal subsidies make water so cheap that western farmers dependent on this would lose by investing in more effective irrigation. Worldwide, about 23% of water is withdrawn for generating energy, industrial processing, cleaning and removal of waste in developed countries. Domestic and municipal use accounts for about 13 – 16% of worldwide withdrawals in industrialized countries like Canada and USA (Glieck 2016).

As at 2006, only about 87% of 5.7 billion world population obtain water from improved sources (WHO/UNICEF, 2014). Out of these, about 54% depended on piped connection in their community, while 33% were on wells or boreholes. There were high disparities in the use of safe drinking water sources over the developing areas of Asia. Due to deficiencies in safe water availability, unsafe alternative drinking water sources such as dug well, unprotected spring, pond, cart with tank/drum and trucks are used around sub-saharan Africa countries. Improved drinking water coverage in the rural areas of sub-Africa is still lower than that of other regions (Ademiluyi and Odugbesan , 2008; Boelee *et al.,* 2013). It increased from 49% in 1990 to 58% in 2006 which covered about 207 million people as at 2006 (WHO/UNICEF, 2014).

Annual global water withdrawal grows from about 3790mg^3 in 1995 to about 4430 km^3 in 2000 and is expected to reach about 5240 mg^3 by 2025 (UN-HABITAT, 2015). Although water consumption rate is growing slowly at 1.33%, it is estimated to affect two-third of the human population. Globally drinking water has received considerable attention on the marked difference between escalating demand and shrinking supplies. Over the past few decades population growth water consumption has outpaced global drinking water sources which had changed in structure of food demand.

Countrywide, regional, and seasonal water scarcities in developing countries pose severe challenges for national governments and the international development community. The challenges of growing water scarcity are exacerbated by the increasing costs of developing new water, wasteful use of already developed water supplies, degradation of soil in irrigated areas, depletion of groundwater, water pollution and its impact on human health, and the massive subsidies and distorted incentives that govern water use.

2.3.2 Sources of water supply in communities of Nigeria

According to McDonald *et al.* (2016), water supply is the provision of water for domestic, agricultural (irrigation) and industrial purposes. Velis *et al.* (2017) observed that the accessibility to water in most communities generally is not satisfactory. People are force to collect water from the stream far from their houses because that is the only means they could obtain water for domestic use. It has resulted to major source of contacting water borne diseases. As the communities population expands, the quality of water available to them become unreliable hence, they tend to depend on sources of water supply such as rain harvesting, spring, stream, pond and hand-dug well. Those communities sited by the riverside depend on water from the river or stream which are indirectly medium of transporting polluted water from the upper stream. In other words, those sited far from natural sources of water suffer by going extra mile to obtain water. Many struggles at the well sites or public boreholes to obtain water that is not sufficient for use in the household.

2.3.4 Domestic water demand and supply in Nigeria

The pattern of domestic water demand in communities are dynamic and changing rapidly with increasing population per capita income and level of improved water supply (Abaje *et al.*, 2014). In Nigeria, the State governments are responsible to provide safe portable water to the residents of their respective jurisdiction while the Local government areas serve as the supervisory stakeholder as well as providing and monitoring of rural water projects like the wells and boreholes (Shittu *et al.*, 2010). Recently the provision of pipe-borne water and boreholes is by both public and private organizations. Some supporting organizations like European Union, UNICEF, UNDP engage in provision of boreholes to the rural areas.

Large quantities of water are required for personal hygiene, cooking, food processing, environmental sanitation, and laundry. The production of portable water from surface or ground supplies usually results in a variety of waste streams, that are not suitable for discharged to the environment (Lee *et al.*, 2010). Water supply are purified or treated to get rid of harmful substances or reduce them to minimum permissible limit to make them safe and fit for human consumption or suitable for the intended general domestic uses. According to Lade and Oloke, (2015), as socio-economic status of the people increases, demand also increases. Due to inadequacy of sources of water, the household members have to seek for water by all means from the available sources to meet their demand. Most government water supply projects in Nigeria are ill-conceived. They degenerate fast and fail to meet public water demand. They are in many instances abandoned thereby contributing limited impact of sustainable water delivery services in the community.

2.3.5 Challenges for Improving Water Supply

Water resources development efforts in Nigeria have so far been centered on the construction of dams and boreholes. In urban cities, pipeborne water, boreholes are often constructed and wells in rural areas for provision of water supply. Irrigation infrastructure for agriculture and the generation of hydro-electric power are also encouraged. The other areas of water resources development; control of floods and erosion, watershed management, improvement of navigation, promotion of recreation use of water, fisheries development and wild life conservation, pollution abatement and sediment or salinity control have received little or no attention. Water supply in Niger State, irrespective of the fact that several public water works exist and have been in operation for several years, hardly is any performing efficiently. Most urban and semi-urban or medium sized towns lack effective public water systems that could ensure regular supplies to the population. The output from most systems of water sources meet only a small percentage of the water need in the cities (Lee *et al*., 2010).

Paradoxically, irrespective of the proliferation of water management agencies in the country coupled with a laudable policy spelling out strategies and attainable targets, all the states are still facing water demand and supply problems. Some of these problems border on mobility to supply adequate volume of water, inadequate proper water-works management, lack of appropriate technology and ineffective commercial operations among others (Oyebode, 2019).

Successive governments in Niger State have shown an abject lack of interest in maintenance of water facilities as a culture. Rather than maintain existing infrastructures, they prefer to build new ones even though it might not see the light of the day, some award juicy contracts which might not be executed successfully. Where they are forced by public condemnation to make repairs, such repairs are more of palliatory than permanent solutions. The result is that environmental decay continues to erode all hope of the communities in developing Countries especially in Nigeria.

Rainwater harvesting (RWH) is any human activity involving collection and storage of rainwater in some natural or artificial container either for immediate use or use before the onset of the next season for domestic, agricultural, industrial and environmental purposes (Mwenge-Kahinda *et al*., 2010; Otti, & Ezenwaji, 2013). The concept of RWH systems can vary from small and basic, such as the attachment of a water bucket to a rainwater downspout, to large and complex, such as those thatcollect water from many hectares and serve large numbers of people (Gur, 2010; Roebuck *et al*. 2011). In rural areas, the most common technique is small-scale rooftop rainwater harvesting (Samaddar *et al.,* 2014).

Rainwater harvesting technology involves three basic stages, namely catchment areas (rooftops and land surfaces), conveyance systems (plastic or corrugated iron gutters) and collection devices (storage tanks) (UNEP, 1982). The quality of rainwater is directly related to the cleanliness of the atmosphere, cleanliness and quality of material used for catchment surface, gutters and storage tanks (Fry *et al.,* 2010). In areas where the rooftop is clean, impervious, and made from non toxic materials, roof rainwater is usually of good quality and does not require much treatment before consumption (Lekwot *et al.,* 2012). The concentration of contaminants associated with a given rainfall event tend to reduce exponentially with time following the beginning of the event. Therefore, diverting the initial portion of runoff away from the storage device will mean that the quality of water entering storage is improved and the need for subsequent treatment reduced or even eliminated altogether (World Health

Organisation, 2004; Boelee *et al.,* 2013). Availability of adequate and clean water for household uses is an enormous problem for rural households in developing countries (Esterhuyse, 2012). RWH has the potential of meeting the water needs of these rural com-munities (Ekwe *et al.,* 2014). Likewise, rainwater harvesting in urban areas can provide supplemental water for the city's requirements (Devi *et al.,* 2012; Ekpoh and Nsa, 2011). One reason the provision of safe drinking water is of paramount concern is that 75% of all diseases in developing countries arise from polluted drinking water (Third World Academy of Science (TWAS), 2002). Each day, 25,000 people die from use of contaminated water and several more suffer from water borne illnesses (Mason, 1996). About half of the people that live in developing countries do not have access to safe drinking water and 73% have no sanitation, some of their wastes eventually contaminate their drinking water supply leading to a high level of suffering. More than five million people die annually from water-borne diseases. Of these, about four million deaths (400 deaths per hour) are of children below age of 5 years. The lack of safe drinking water also stunts the growth of 60 million children per year (WHO-UNICEF, 2015). Contamination of drinking water by urine of the rodent species '*Mastomys natalensis*' has been implicated in the spread of a disease, Lassa fever, an acute viral haemorraghic disease endemic in parts of West Africa, including Nigeria (Public Health Agency of Canada, 2010). As much as one-tenth of the global disease burden could be prevented by improving water supply, sanitation, hygiene and management of water resources (Vilane & Mwendera, 2011; WHO, 2014).

The provision of water for domestic and other uses in rural and urban centres is one of the most intractable problems in Nigeria today, with 52% of Nigerians lacking access to improved drinking water supply (Orebiyi *et al.,* 2010; Lekwot *et al.,* 2012). Nigeria is endowed with enormous surface and groundwater resources, yet the provision of potable and safe water supply is still inadequate. (Nwankwoala, 2011). The Sustainable Development Goals (SDGs) of halving by 2018 the proportion of people without sustainable access to adequate and affordable safe drinking water will be hard to achieve due to low levels of existing coverage, but this will become almost impossible if sustainability levels cannot be improved (Nwankwoala, 2011). Despite the seeming intractable problem of water scarcity in Nigeria, the high neonatal and childhood morality due to diarrheal dis-eases and the common practice of RWH.

CHAPTER THREE

METHODOLOGY

3.1 Research Design

This study used both quantitative and qualitative methods of data analyses. At the data collection stage, the study area was identified and methods of sampling and administration of research instruments was conducted. This was followed by data analysis stage, where data is collated, summarized and presented including composite water sample test from laboratory analysis. Finally, the collected data was coded, entered and checked for consistency before keying into the SPSS software for further processing, and was analyzed using SPSS to obtain information on household characteristics such as age, education and awareness levels, household incomes, household size.

3.2 Sources of Data

Both primary and secondary data were used for this study. Direct surveys, observation, rainfall records and water samples were collected from the available rainwater harvested sources at different places, time and also in all the raining months in that area. Data were generated from already existing literature and journals related to the study and were used to supplement primary data generated. Secondary data was sourced from text books, journals and the related materials from libraries, boards and conference articles related to the study area were consulted for relevant issues and recent data. .

Hydrological data (Rainfall) record of 33 years (1987-2020) was collected from NIMET stations in Old Airport Road, Minna. Hydrological analysis was also carried out to describe the relationship between seasonal patterns and availability and to establish a relationship between climate and rainfall variability, hence reliability of rainwater as an alternative water supply.

3.3 Method of sampling and collection of rain water samples

The first field work was to identify roof materials and types that are commonly used in Tayi village for rainwater harvesting. Sample locations were randomly picked where rainwater harvesting system was already in existence. A random sampling technique was employed in selecting the sampled locations. Two (2) predominant harvested rainwater sources identified, namely: corrugated iron roofing sheet and aluminum roofing sheet. Samples of harvested rainwater from the two sources were collected. Care was taken to ensure that no accidental contaminations occur during sampling. Sample containers of 5cl were soaked in acid solution overnight prior to sample collection, followed by proper rinsing with distilled-deionized water, before the samples to be analyzed were collected from the rainwater harvested sources. The temperature and pH of the rainwater samples were measured immediately after collection with hand held Temp/pH meter. Samples for microbial analysis were kept with a sterilized capped bottle to arrest the further growth of bacterial prior to analysis. They were then taking to the Federal University of Technology Minna, Department of Water Resources, Aquaculture and Fisheries Technology laboratory for microbial and physiochemical analyses.

3.4 Data analysis and presentation

Data was analyzed and presented quantitatively and qualitatively using different statistical. Descriptive statistics; Mean, range, standard deviation and coefficient of variation (CV) were determined. The parameters were tested for any significant difference amongst the sources. Logistic regression model with an entry selection process was used to analyze and estimate the dependent variable as adoption of a particular technique and independent variables.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.1 Trend Analysis of Rainfall in Tayi Village

The intra seasonal variation of rainfall over Tayi village shows that rainfall generally begins in April, increase until the mount of November and decrease thereafter until cessation takes place completely in November. Figure 4.1 shows that about 50% of the annual rainfall total accumulates in three heaviest rainy months of July, August and September and lowest in the months of January, February and December. There is thus a marked dry and rainy season.

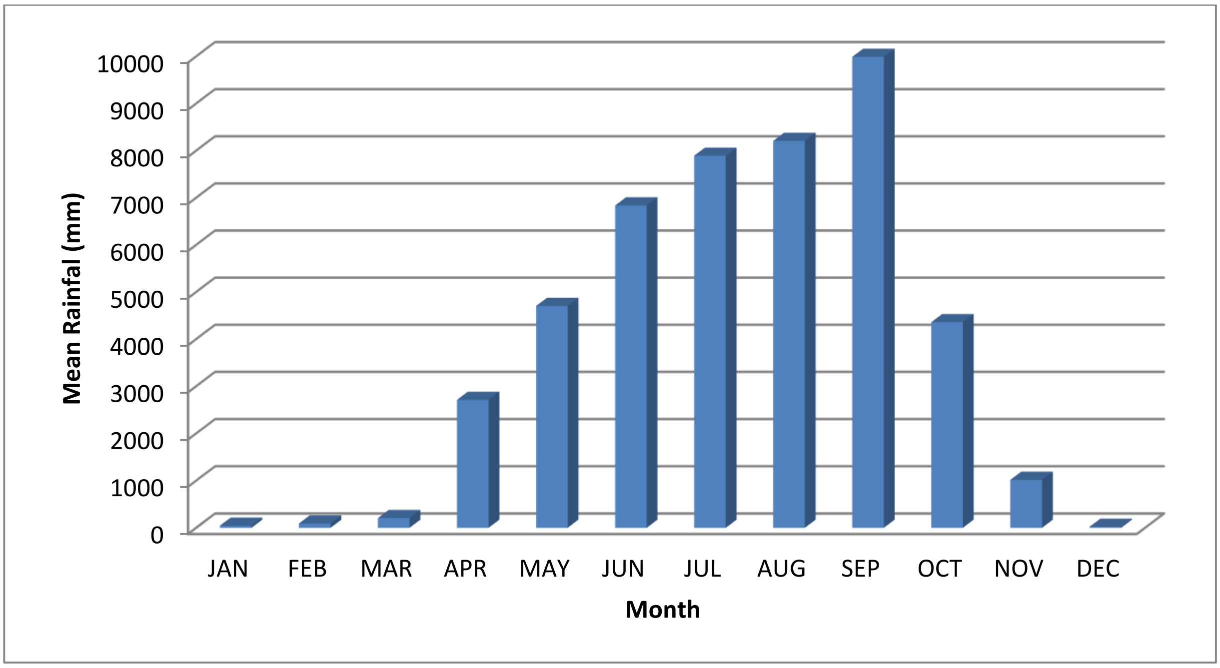

Figure 4.1: Mean Monthly Rainfall of Tayi Village

Figure 4.2 shows rainfall trend of Tayi Village between 1987 – 2020 was also analyzed; the deviation of mean annual values of rainfall over thirty (30) years was shown in Figure 4.2. The deviation of rainfall negative between 1987and 1988, between 1989 and 1991, the deviations are positive over a period of five years. On decadal basis, the years 1991 and 1994 have the highest deviations while the remaining years have very low deviations. The rainfall deviations increased between 1998 and 1999. On decadal basis, the years 1998, 1999, 2004, and 2006 have positive rainfall deviations while the remaining years have negative and least rainfall deviations. Between the year 2008 and 2016, the rainfall deviations were positive in the year 2008, 2010 and 2011. However, the deviations were lowest in the year 2012 and 2014. The years 2009, 2013, 2015 and 2016 have a negative rainfall deviation within the area. This implies the rainfall between 1987 and 2020 have a slightly decreasing trend (graphically) in the study area. The result of the study concludes that as water is very important to life the slight decreasing trend in rainfall will have significant effect on water accumulation in the area.

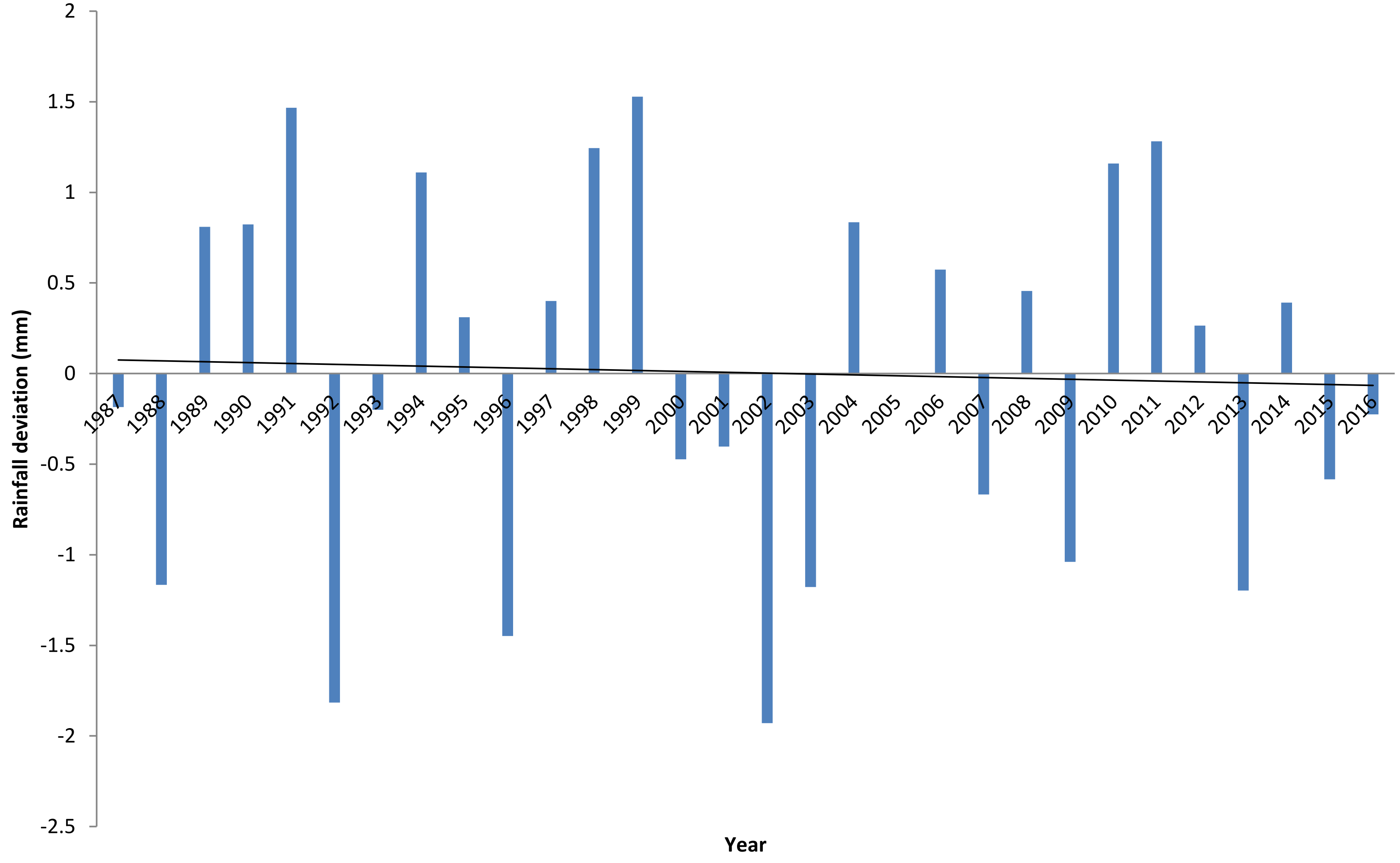

Figure 4.2 Rainfall deviation

Table 4.1 shows the trend of rainfall over thirty years. The months of January, February, March, April, May, July, August, September, November, December have Z values less than 1.96 meaning that these months have insignificant trend. The months of June and October have z values greater than 1.96. This implies that the trends were significant. The month of October has a positive trend while the month of June has a negative trend. On annual basis, the rainfall records have decreasing trend.

Table 4.1 Trend analysis of rainfall using Mann Kendall test

Month	tau	S value	Zvalue
Jan	0.0713	31	0.6612
Feb	0.0506	22	0.4629
March	-0.0989	-43	-0.9257
Apr	0.0667	29	0.6172
May	-0.0483	-21	-0.4408
June	-0.2552	-111	-2.4246
July	-0.0345	-15	-0.3086
August	-0.2046	-89	-1.9397
Sept	0.2046	89	1.9397
Oct	0.3195	139	3.0417
Nov	0.1563	68	1.4768
Dec	0.0667	29	0.6172

4.2 Supply and demand variation of water in Tayi Village

The analysis in Table 4.2 shows the volumes of runoff an 80 m^2 roof can collect 82,835 L/yr. This means 227 L/day assuming a constant withdrawal, throughout the year. For a family of five people, this means 45 L/person/day, which is quite a substantial amount of water in the urban areas, provided there is sufficient storage. presents the cumulative harvested water. Tayi village is indeed a very well-watered area with substantial amounts of rainfall available each year. It was also observed that the greater the annual rainfall the larger the tank size that is required. (Table 4.2). Figure 4.3 shows that the maximum storage is required in October with an additional storage capacity of 17 m^3 (17,000 L).

Table 4.2: The cumulative harvested water

Month	Average rainfall [i] (mm)	Roof area [RA] (m^2)	Runoff coefficient [C]	Monthly runoff harvested [i×RA×C] (m^3)	Cumulative runoff harvested (m^3)
January	0.00	0.00	0.00	0.00	0.00
February	0.00	0.00	0.00	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00
April	117.1	80	0.8	7.49	15.11
May	153.2	80	0.8	9.80	24.91
June	188.2	80	0.8	12.04	36.95
July	179	80	0.8	11.46	48.41
August	149.2	80	0.8	9.55	57.96
September	192.6	80	0.8	12.33	70.29
October	183.6	80	0.8	11.75	82.04
November	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.00

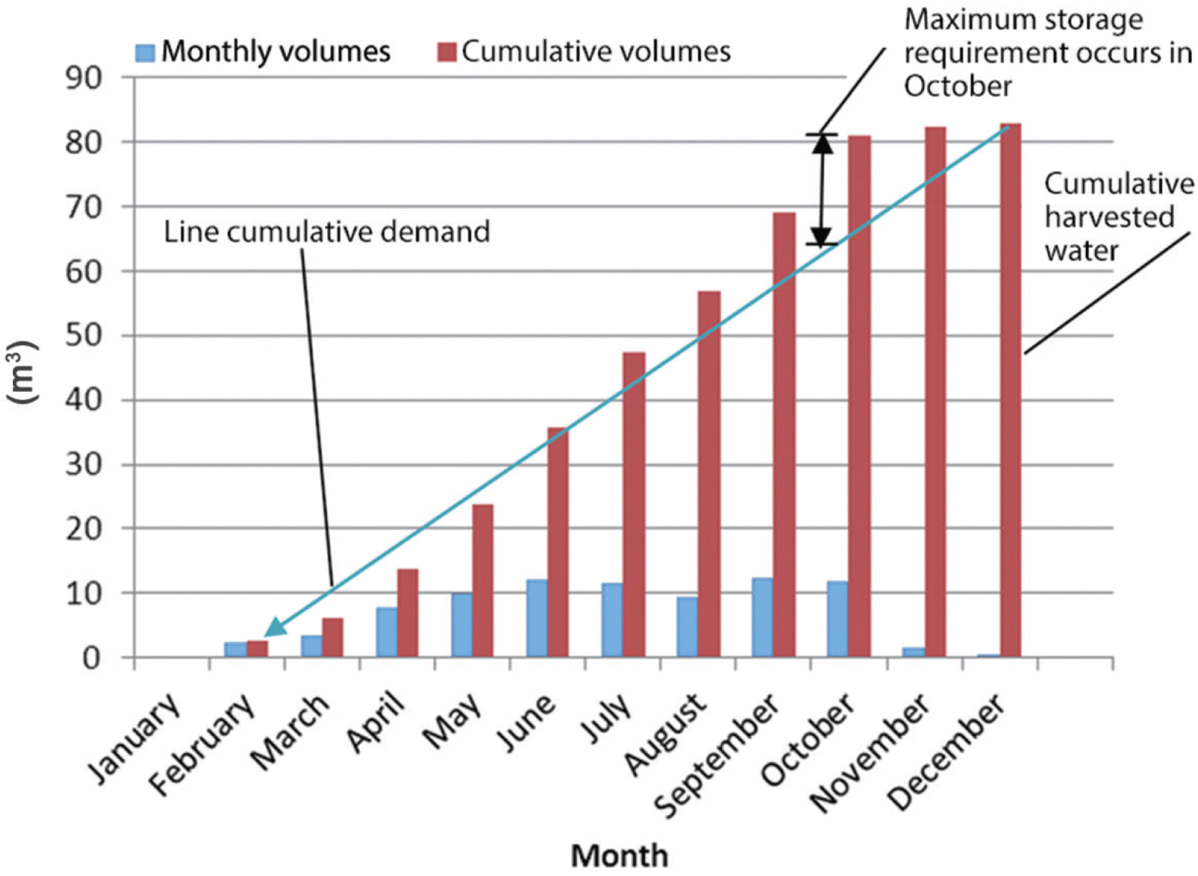

Figure 4.3 Cumulative harvested rain water

Rainwater harvest is found to be technically feasible based on the prevailing rainfall pattern. Over 90% of households have a rooftop constructed from technically appropriate materials. Results of the research performed in Tayi village indicate that an average roof of 80 m^2 will collect 82,835 L/yr (45 L/person/day) for a family of five people, which is near the water demand for drinking and cooking purposes. Hence, the capacity of a storage tank and the catchment area required for an all-purpose water supply system based on RWH is quite large. These can be reduced to affordable sizes, by collecting and storing water for cooking and drinking only while non-potable uses are supplemented by water from other sources.

In determining water demand level within Tayi, data on the average distance of household sources of water were considered as the dependable variable, which is correlated against the data generated from the average household size, average quantity of water demand, and average quantity of water obtained in demanding for water as independent variables. The sources of water in Tayi village range from shallow wells, boreholes and rainfall harvesting. In dry seasons most sources especially the boreholes and wells are often stressed beyond the expected level. Many households usually prefer obtaining water from a specific source and will not mind to stay on queues for long hours. The inability of households obtaining enough water for use become paramount during the wet season when water table level recharge the wells and the boreholes including the surface water. The availability of water during this period is retered by not meeting the required quality.

Table 4.3: Water demand level

Dependent variable	**Independent variable**		
Distance (X- values)	Household size (Y- values)	Quantity of Water Demand	Quantity of Water obtained
17	26	21	20

	Best-fit	Standard	95% confidence interval	
Parameter	Value	Error	from	to
Slope	0.4673	0.1468	0.1729	0.7616
Y intercept	19.531	5.454	8.594	30.467
X intercept	-41.799			

Correlation coefficient (r) = 0.3944. r squared = 0.1555

Standard deviation of residuals from line (Sy.x) = 14.757

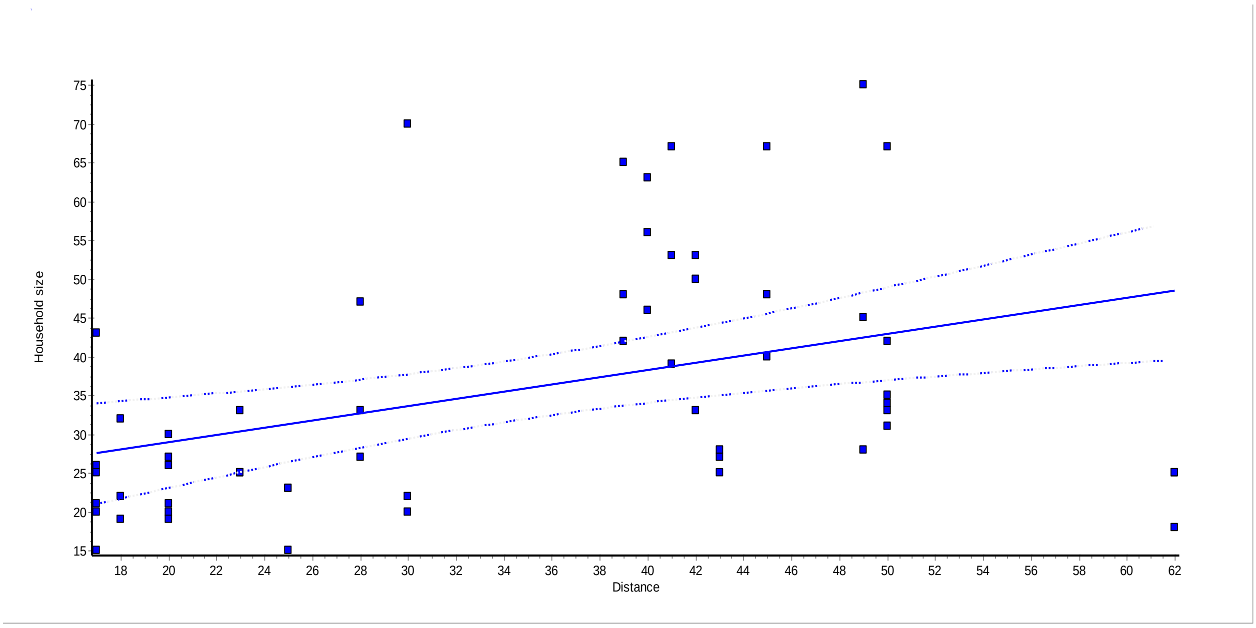

Figure 4.4: Level of water demand in Tayi village

The distance of household from source of water is the function of household-size in demanding for water. Figure 4.4 reveals that demand for water depend on the viability of the household and capability to afford the required standard of water in need. The quantity of water obtained by the household is a function of distance and the size of the household from the source. Since r=0.39, there is relationship between the distance of household to the type of sources of water of the household. In figure 4.4 the farther the distance of sources of water from the household, the less water is been used by the households. This implies that most households prefer to fetch water from the close by sources. Whenever there is scarcity the water vendors become the major source, they could depend on because they go to any distant to fetch water which are sold to the households.

Table 4.4: Sources of water

DEPENDENT VARIABLE	**INDEPENDENT VARIABLE**				
Purpose of Demand	Multiple Source	Borehole	Water Vendor	Rainwater Harvest	Well
	5	4	3	2	1
43	45	35	18	5	15

It is revealed from this study that borehole water account for 80% of highly significant sources of water demand in households. Many households prefer the borehole water because it does not require treatment before use and the accessibility to both class of households in the study area, well water 60%, rainwater 45% and Water vendor is 40%. Moreover, accessibility, quantity and quality are always attached to any source of water household intends to use, no matter the condition of the source.

4.2.2 Relationship between Water Supply and Water Demand

In determining whether the water supply matches the demand, the data generated from average quantity of water acquired by the individual households against the educational attainment level of the household heads, Purpose of household demand for water and average expenses on acquiring water per month are computed to interpret the significance effect of the independent variables on the dependant variable.

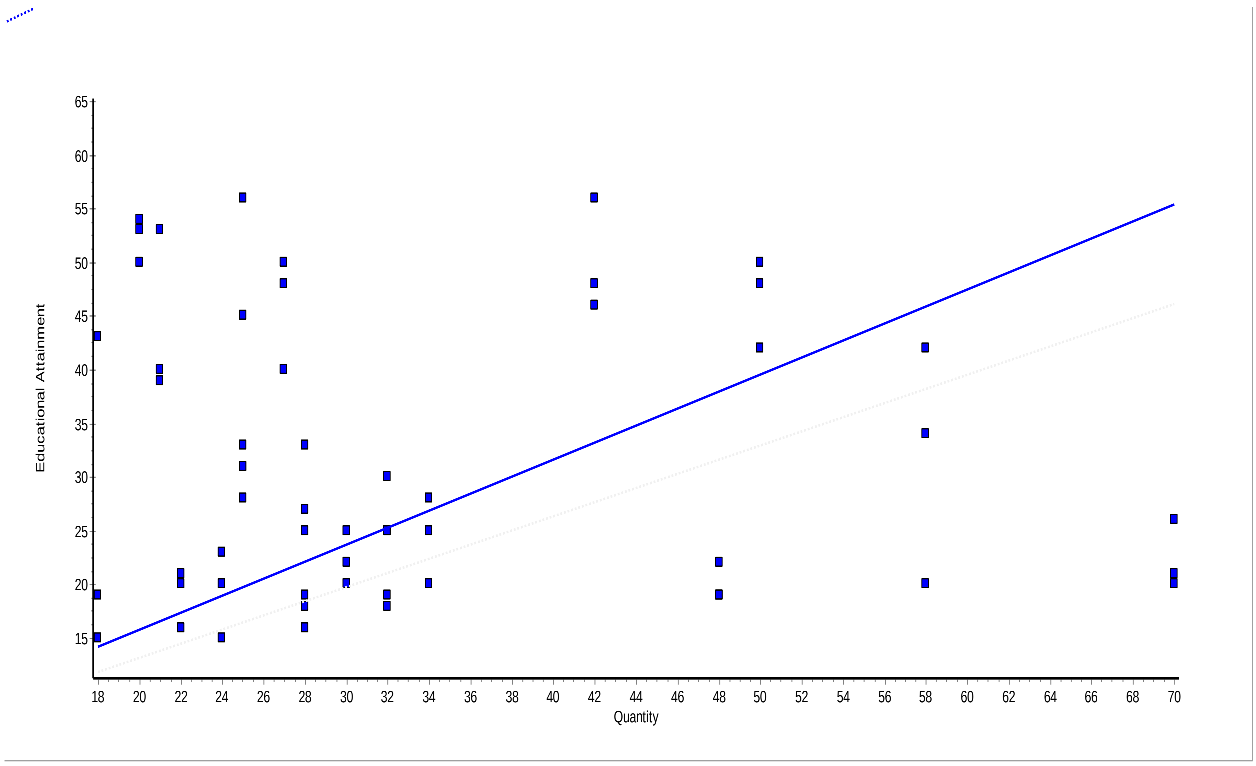

Figure 4.5: The relationship between Water Supply and Demand in Tayi

Figure 4.5 reveals that quantity of water demand is a function of the education attainment of the household. It was revealed from the study that household heads with higher educational attainment demand for better water quality and quantity for domestic activities. As revealed on plate I, women and children waste a lot of time on queue at boreholes (Plate I, II and III). The household heads with higher educational attainment desire to obtain better and high standard of living. Since the cal-t = 11.944, and tab-t = 2.060, there is significant difference between the demand for water from different sources which could be based on interest of the household due to exposure. Therefore, adequacy of water supplied to meet the demand of each household based on WHO standard can hardly be satisfied in most medium-sized towns.


Plate I: Women waiting on queue at a public borehole Tayi village


Plate II: Children waiting on queue at a public borehole Tayi village

Plate III: Source of Water from a commercial borehole in Tayi village

Plate IV: Source of Water from a commercial borehole in Tayi village

4.3 Quality of rainwater collected from available roofing sheets to ascertain their impact on harvested rain water

4.3.1 Physio-chemical and microbiological parameters of collected rainwater

The physiochemical and microbiological rainwater quality results are presented in Tables 4.5 and 4.6 respectively. The temperature recorded was in the range of 26.5-27°C for corrugated iron roofing sheet and Aluminum roofing sheet recorded an average of 27°C in all samples and the concrete tanks ranged from 23-25°C. For pH, electrical conductivity and total dissolved solids (TDS), metal tanks recorded values within the following ranges; 5.1-6.2, 20-62 µS/cm and 10.5-31.5 mg/L respectively. Aluminum roofing sheet ranged from 5.2-6.2, 30-40 µS/cm and 15.0-20.2 mg/L. This findings was inline with the study of Akanmu (2012) who discovered that the mean pH values of water ranged between 6.75 and 7.82 which are however within the tolerable limits recommended by both WHO and NSDWQ.

Table 4.5. Mean ± SD*Trace and Heavy Metals In Harvested Rainwater

Parameter	**Corrugated iron roofing sheet (Zinc)**		**Aluminum roofing sheet**		**WHO**
	Mean ± SD	CV (%)	Mean ± SD	CV (%)	
Ca (mg/L)	3.86±1.6	41.45	3.93±0.7	17.8	75
Mg (mg/L)	2.04±1.6	78.43	1.36±0.7	51.47	50
Pb (mg/L)	ND	-	ND	-	0.05
Cr (mg/L)	ND	-	ND	-	0.05

*Mean result (n=10) for each storage medium

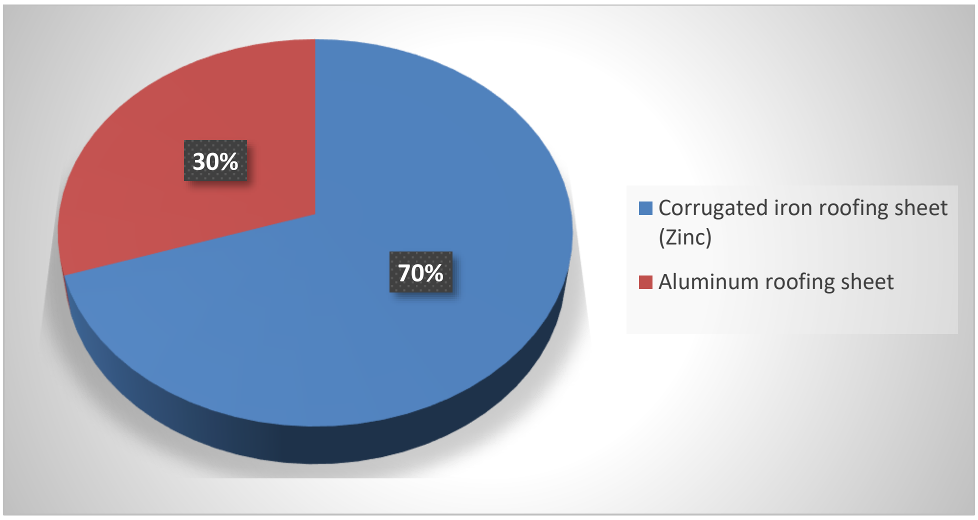

Figure 4.6: Trace and heavy metals in harvested rainwater from corrugated iron roofing sheet and Aluminum roofing sheet.

Turbidity (NTU) ranged from 1.0-1.5, 1.0-1.2 and 1.0-1.5 in corrugated iron roofing sheet and Aluminum roofing sheets respectively. Total acidity values were within the following ranges 1.5-8.5mg/L in corrugated iron roofing sheet. Aluminum roofing sheet (in mg/L) 2.1-6.0 respectively. Corrugated iron roofing sheet gave the range for nitrate, sulphate and chloride value as <0.01-3.1, 1.8- 5.8 and <0.01-0.90 mg/L respectively. Aluminum ranged from 0.2-2.1, 2.01-5.3 and <0.01-1.20 mg/L for nitrate, sulphate and chloride.

The mean concentrations of trace and heavy metal detection in the samples analysed is shown in Table 4.5. Calcium has mean values of 3.86 ±1.6, 3.93 ±0.7 and 6.14 ±2.4 mg/L in corrugated iron roofing sheet and aluminum respectively. Magnesium means values found in corrugated iron roofing sheet and aluminum. Al was only detected in corrugated iron roofing sheet samples with a mean concentration of 0.02 ±0.01mg/L. Iron was recorded in all samples analysed from the two sources (corrugated roofing sheets and aluminum), with mean values of 1.71 ±0.4, 0.90 ±0.3 and 0.91 ±0.2 for corrugated iron roofing sheet and aluminum roofing sheet.

Table 4.6 Mean ± SD* of Physiochemical Parameters Result Of Harvested Rainwater

Parameter	**Corrugated iron sheet (Zinc)**		**Aluminum roofing sheet**		**NSDWQ**	**WHO limits**
	Mean ± SD	CV (%)	Mean ± SD	CV (%)		
Temp.(^{0}C)	28.8±0.4	1.49	25±0.0	-	21	23
pH	6.74±0.4	7.23	5.64±0.3	5.31	6.5-8.5	6.5-8.5
Conduct. (µS/cm)	82.4±13.1	26.8	32.4±4.3	13.27	1000	1000
TDS (mg/L)	15.68±6.5	45.42	16.62±2.3	13.84	500	500
Turbidity (NTU)	1.16±0.2	0.001	1.06±0.01	0.94	5.0	5.0
Acidity (mg/L)	8.6±2.1	24.41	3.36±1.2	35.71	50	50
NO_3 (mg/L)	0.86±1.2	68.18	1.37±0.8	58.39	50	10
SO_4 (mg/L)	2.13±1.4	38.15	3.57±1.2	33.61	100	100

Cl (mg/L)	13.72±0.08	16.33	0.38±0.06	15.79	20	20
Mg (mg/L)	1.23±1.5	16.33	0.38±0.06	15.79	20	20
Ca (mg/L)	4.21±2.2	16.33	0.38±0.06	15.79	20	20
TH (mg/L)	16.01±6.1	16.33	0.38±0.06	15.79	20	20
TA (mg/L)	20.00±8.8	16.33	0.38±0.06	15.79	20	20
EC (µS/cm)	62±25	16.33	0.38±0.06	15.79	20	16.33

The sources of harvested rainwater showed statistically significant differences ($p<0.05$) in some quality parameters such as pH, Electrical conductivity, Total dissolved solids, acidity, trace and heavy metals determined in harvested rainwater samples. The difference in the values of the parameters of different sources shows the impact of roofing sheets rainwater harvest. Corrugated iron roofing sheet showed the most differences in the parameters owing to the release of the component materials of the roofing zinc., pH was found to be lowest in corrugated iron roofing sheet with a mean value of 5.53±0.4 and coefficient of variation (CV) of 7.23% which show no significant variation in all corrugated iron roofing sheet sampled (Table 4.6). The pH of aluminum roofing sheets were within the permissible limits of the W.H.O standards and Niger Standard Drinking Water Quality for potable water, but that of the corrugated iron roofing sheet was found below (not within the range) the acceptable limits.

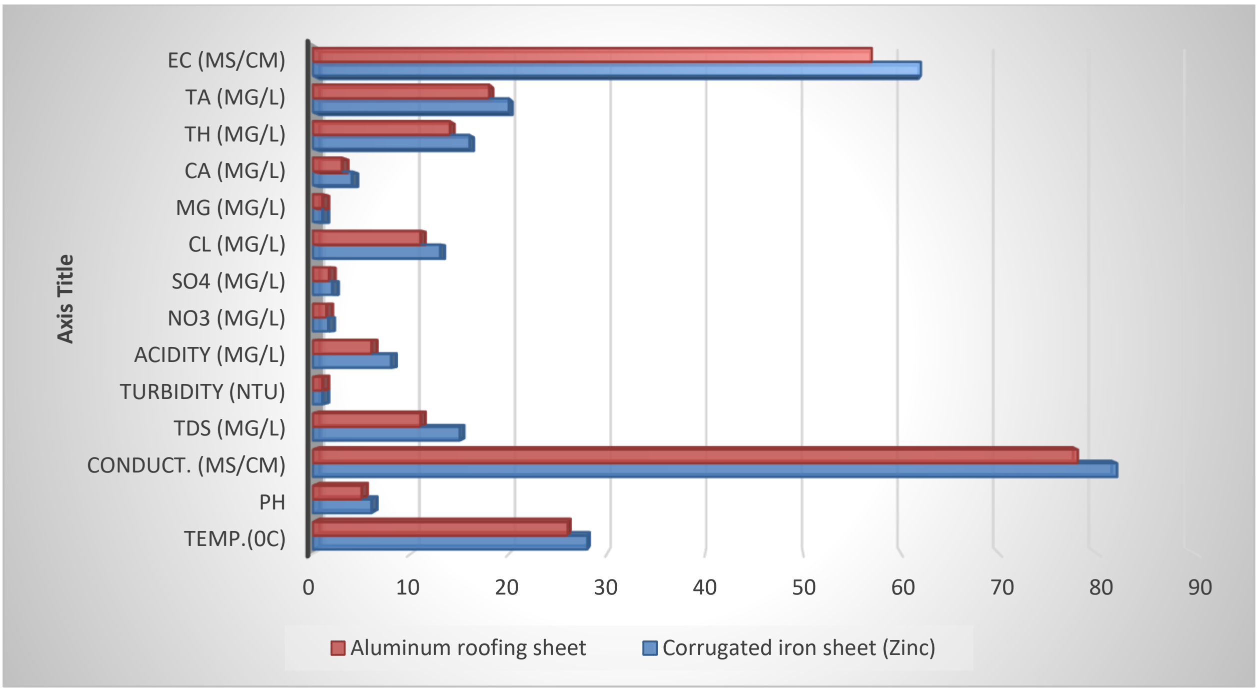

Figure 4.7: Physiochemical parameters result of harvested rainwater from corrugated iron roofing sheet and Aluminum sheet.

Electrical conductivity, total dissolved solids (TDS) and acidity were found to vary significantly ($p<0.05$) between corrugated iron roofing sheet. Aluminum roofing sheets were found to vary significantly in electrical conductivity and total dissolved solids. Conductivity was highest in corrugated iron roofing sheet (Figure 4.6) which can be explained from the low pH and the leaching of corrugated iron roofing sheet components into rainwater harvest. Turbidity shows no significant difference ($p<0.05$) in the sources of rainwater harvest. Low values of turbidity within the range of 1.0-1.5 NTU were determined in all rainwater sampled. This conforms to the acceptable standards and guidelines for potable water quality of 5.0 NTU of W.H.O. Nitrates, sulphates and chlorides results (Figure 4.7) in samples from the two sources no significant difference ($p>0.05$) which indicated no contribution to the parameters from the sources of the harvest.

4.3.2 Trace and heavy metals

The levels of calcium and magnesium varied significantly in the two sources of rainwater harvest. The highest values were found in the aluminum, this expectedly is due to the calcium carbonate as the major constituent of aluminum. Calcium and magnesium however showed no significant difference in corrugated iron roofing sheet. Zinc, iron and copper levels were found to be highest in corrugated iron roofing sheet (Figure 4.6). The mean values of copper and iron found in corrugated iron roofing sheet exceeded the recommended limits of W.H.O (Table 4.6). This can be attributed to the low pH of the rainwater in corrugated iron roofing sheet which increases the potentials for the leaching of corrugated iron roofing sheet. Another important factor in the leaching of the corrugated iron roofing sheet could be attributed to the location slightly acidic rainwater. The difference between the concentration of zinc, copper and iron were found to be significant ($p<0.05$) between corrugated iron roofing sheet and aluminum, also between corrugated iron roofing sheet. In aluminum the levels of zinc, iron and copper showed no significant difference ($p<0.05$). Corrugated iron roofing sheet exceeded the W.H.O allowable limits for iron and copper.

4.3.3 Microbiological analysis results

The microbiological analysis results (Table 4.7) show that all harvested rainwater samples tested had coliforms detected. The confirmatory coliform test was positive in the samples. Of all the samples, rainwater samples in aluminum has the lowest mean total bacteria counts (TBC) of 860±20.5 MPN/100mL (Table 4.7), followed by the corrugated iron roofing sheet having mean TBC value of 1060±50.5 MPN/100mL.

Table 4.7 Mean ± SD* of Microbiological Parameters Of Harvested Rainwater

Parameter	**Corrugated iron sheet (Zinc)**	**Aluminum roofing sheet**	**Concrete**	**WHO limits**
	Mean ± SD	Mean ± SD	Mean ± SD	
Total Bacteria count MPN/100ml	1060±50.5	1560±36.0	860±20.5	0
Total Coliform (CFU/ 100ml)	342±23.5	560±12.8	200±16.9	0
Confirmatory faecal coliform test	**+ve**	**+ve**	**+ve**	**-ve**

From the results (Table 4.7) The most contaminated were the corrugated iron roofing sheet as the level of microbial contamination varied significantly ($p<0.05$) in the sources.

The difference in the microbial levels (Figure 4.9) has been attributed to the pH variations and temperature of the harvested rainwater. Studies have found some correlations between pH and growth of coliforms in rainwater. The total coliform was lowest in concrete tanks which have the highest mean pH value in this study. This trend was however, not observed in corrugated iron roofing sheet with pH values lower than that of aluminum was lowest. This difference has been reported in a study where the effect of temperature was found to have a significant difference in the levels of micro-organisms in rainwater in different sources. It has been observed that corrugated iron roofing sheet maintain higher temperature than the aluminum roofing sheeets and hence the varying micro-organisms level. The same trend is however not followed when the microbial levels of harvested rainwater in corrugated iron roofing sheet which suggests that the effect of pH on microbial level impacted more than the temperature for which no significant difference ($p<0.05$) was observed.

The microbiological results show that all the harvested rainwater samples did not pass the microbiological examinations (Table 4.7). The reports in the literature are similar to that obtained in this study. Analysis showed that the selected sources of harvested rainwater was polluted and unsuitable for drinking. Total coliform of rainwater in these sources is an indication of faecal contamination. This shows that various catchment systems and roofs have waste matters being transported into collection. The presence of faecal coliform in water indicates that faecal pollution had occurred. This poses great danger to human health. Contamination of water by human and animal waste deposits constitutes the most common mechanism for transmission of micro-organisms to humans. These pathogenic organisms are responsible for the infection of the intestinal tracts and the diseases caused include; diarrhoea, cholera, bacillary dysentery, typhoid, hepatitis and so on. The incidence of water borne diseases can therefore be attributed to untreated or poorly treated stored rainwater that contains pathogens.

4.4 Summary of Findings

The findings show the seasonal variation of rainfall over Tayi village, about 50% of the total rainfall accumulates in three heaviest rainy months of July, August and September and lowest in the months of January, February and December. The negative deviation of rainfall is between 1987and 1988. Between 1989 and 1991, the deviations are positive over a period of five years. On decadal basis, the years 1991 and 1994 have the highest deviations while the remaining years have very low deviations. The rainfall deviations increased between 1998 and 1999. On decadal basis, the years 1998, 1999, 2004, and 2006 have positive rainfall deviations while the remaining years have negative and least rainfall deviations. The months of January, February, March, April, May, July, August, September, November, December have Z values less than 1.96 meaning that these months have insignificant trend. The months of June and October have z values greater than 1.96.

The findings also established that the volumes of runoff an 80 m^2 roof can collect 82,835 L/yr. This means 227 L/day assuming a constant withdrawal, throughout the year. For a family of five people, this means 45 L/person/day, which is quite a substantial amount of water in the urban areas, provided there is sufficient storage. presents the cumulative harvested water. It was also observed that an average roof of 80 m^2 will collect 82,835 L/yr (45 L/person/day) for a family of five people, which is near the water demand for drinking and cooking purposes. Hence, the capacity of a storage tank and the catchment area required for an all-purpose water supply system based on RWH is quite large. These can be reduced to affordable sizes, by collecting and storing water for cooking and drinking only while non-potable uses are supplemented by water from other sources. It further reveals that demand for water depend on the viability of the household and capability to afford the required standard of water in need. The quantity of water obtained by the household is a function of distance and the size of the household from the source. The distance of sources of water from the household, the less water is been used by the households.

It was discovered that temperature recorded was in the range of 26.5-27oC for corrugated iron roofing sheet and Aluminum roofing sheet recorded an average of 27oC in all samples and the concrete tanks ranged from 23-25oC. For pH, electrical conductivity and total dissolved solids (TDS), metal tanks recorded values within the following ranges; 5.1-6.2, 20-62 µS/cm and 10.5-31.5 mg/L respectively. Aluminum roofing sheet ranged from 5.2-6.2, 30-40 µS/cm and 15.0-20.2 mg/L. This findings was in line with the study of Akanmu (2012) who discovered that the mean pH values of water ranged between 6.75 and 7.82 which are however within the tolerable limitsb recommended by both WHO and NSDWQ.

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Contamination of water by human and animal waste deposits constitutes the most common mechanism for transmission of micro-organisms to humans.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study focused on rainwater harvesting to meet the potable water supply of resident in Tayi village of Minna. Rainwater harvest is found to be technically feasible based on the prevailing rainfall pattern. The physiochemical properties of rainwater were most influenced by the different types of harvested sources and their component materials. Statistically significant differences were also observed in some physio-chemical quality parameters between corrugated iron roofing sheet and aluminum roofing sheets. The microbiological quality of the harvested rainwater appears to depend, partly, on the handling by users of the rainwater. The results of this study are in agreement with a number of other national and international studies that show the overall poor water quality (microbiological contamination) of harvested rainwater, as the microbiological quality of the rainwater sample were below valid standards and allowable limits for drinking water quality. Whereas, the physiochemical quality parameters conform to W.H.O water quality guidelines, except for the levels of copper and iron in corrugated iron roofing sheet that exceeded recommended limits of

W.H.O. In order to have better quality of harvested rainwater, the catchment roofs and run-offs must be properly washing before the start of rainy season. Harvested rainwater should be treated by adding some disinfecting agents such as chlorine which might help in reducing the risk of microbiological contaminations.

5.2 Recommendations

1. **i.** Due to the type of roofing materials, rainwater should go through proper treatment in order to be used for potable purposes.
2. ii. Public awareness has an important role in collected rain water management.
3. iii. Education, training, and financial supports are needed to encourage people to consider the importance and quality of collected water.
4. iv. For those who have not yet installed a roof, provide more basic supplies at a reduced cost in the market or on a long-term loan basis.

Recommendation for further research

Rainwater harvesting to meet water supply using water from surface runoff

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