# RAINWATER HARVESTING, STORAGE AND TREATMENT FOR DOMESTIC PURPOSES IN KUBWA FEDERAL CAPITAL TERRITORY

BY

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL
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STATE

# CERTIFICATION

This is to certify that "Rainwater Harvesting, Storage and Treatment for Domestic Purposes in Kubwa, FCT" by Ojukwu, Francis Obinna, meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

19·04·2011

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# DECLARATION

I hereby declare that this project work is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any other University or Institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

14|02|2011

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Date

# DEDICATION

I dedicate this project work to God Almighty and to my parents.

# ACKNOWLEDGEMENTS

The successful completion of this research work is not by my efforts alone but by God's grace and the contributions of my supervisor, lecturers, family members, friends, colleagues and well wishers, therefore the contributions of these people have to be acknowledged.

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# ABSTRACT

The scarcity of natural water resources and the increasing growing gap between demand and available supply of potable water in Kubwa led me into this research with a view to provide an alternative source of water supply for domestic purposes in order to mitigate water supply challenges. A total of 200 questionnaires were distributed to enable the researcher examine the level of awareness and adoption of rainwater harvesting techniques within the geographical location under consideration. This study describes the magnitude of rain water harvesting in Kubwa obtained from a house to house survey, their method of rainwater collection, practices, storage and usage. The result of the questionnaires using descriptive statistical method shows that the level of awareness is 100% but the adoption of these noble techniques is poor as only 50% collected rainwater. 83% of the Respondents that collected rainwater attributed their collection to unreliability/inaccessibility of the public water supply amongst other findings. In a bid to improve on this lapses, this project therefore recommended the following; the design of suitable rainwater harvesting structures in theses locality, establishing regional water plans, creating competition in water supply, increasing water supply options for both short and long terms, and other advanced water related technologies of which rainwater harvesting technology belong, and reducing the current waste in water use. Some specific programs to implement above policies are outlined.

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# CHAPTER ONE

## 1. INTRODUCTION

### 1.1 Background of Study

Water is one of the world's most valuable resources. Yet it is under constant threat due to climate change and resulting drought, explosive population growth and waste. (www.gewater.com, 2010).

Growing demands for water, increasing costs of water supply and Spatial variability in climatic factors are resulting in a need for countries/communities to maximise the use of their existing water supplies and make use of hitherto unexploited freshwater resources. (OAS 2010). The source of almost all freshwater is precipitation from the atmosphere, in the form of rain, mist and snow. (Wikipedia, 2010).

Numerous techniques, modern and traditional, for improving the use and augmenting the availability of water resources have been developed and implemented in different parts of the world. These include, among others wastewater reuse and recycling, Rainwater harvesting. In many developing countries, the application of these technologies has been limited by lack of information on the approaches available and how well they work. (OAS, 2010).

#### 1.1.1 Wastewater reuse, reclamation and recycling

Wastewater, in this context, includes sewage effluent, stormwater runoff and industrial discharges. The wateReuse Association (2010) defines reused, recycled or reclaimed water as water that is used more than one time before it passes back into the natural water cycle. Thus, water recycling is the reuse of treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing or replenishing a groundwater basin (referred to as Groundwater recharge). (www.gewater.com, 2010).

Once freshwater has been used for an economic or beneficial purpose, it is generally discarded as wastewater. In many countries, these wastewater are discharged, either as untreated waste or as treated effluent, into water courses, from which they are abstracted for further use after undergoing 'self-purification' within the stream. Through this system of indirect reuse, wastewater may be reused up to a dozen times or more before being discharge to the sea. However more direct reuse is also possible: the technology to reclaim wastewater as potable or process waters is a technically feasible option for agricultural and some industrial purposes (such as cooling water or sanitary flushing) and a largely experimental option for the supply of domestic water (OAS, 2010). In the direct reuse option, it is most important to neutralize or eliminate any infectious agents or pathogenic organisms that may be present in the wastewater. For some reuse application, such as irrigation of non-food crop plants, secondary treatment may be acceptable. For other applications, further disinfection, by such methods as chlorination or may be necessary. (OAS, 2010).

Wastewater reuse for drinking raises public health, and possibly religious, concerns among consumers. The adoption of wastewater treatment and subsequent reuse as a means of supplying freshwater is also determined by economic factors.

### 1.1.2 Water Harvesting

Water harvesting in its broadest sense will be defined as the collection of runoff for its productive use. Runoff may be harvested from roofs and ground surfaces as well as from intermittent or ephemeral watercourses. (FAO, 2010). Water harvesting techniques which harvest runoff from roofs or ground surfaces fall under the term Rainwater Harvesting while all systems which collect discharges from watercourses are grouped under the term:

Floodwater Harvesting. (FAO, 2010). Instead of runoff being left to cause erosion, it is harvested and utilized. It is a directly productive form of soil and water conservation.

Water harvesting has many advantages in rapidly growing cities and under future climate change scenarios. (Clemete, R.S. *et al* 2003).

Rainwater harvesting is one of the promising ways of supplementing the surface and underground scarce water resources in areas where existing water supply system is inadequate to meet demand. (Gould, 2000). Falling rain can provide some of the cleanest naturally occurring water that is available anywhere. This is not surprising, as it is a result of a natural distillation process that is at risk only from airborne particles and from man-made pollution caused by the smoke and ash of fires and industrial processes, particularly those which burn fossil fuels. (www.wateraid.org, 2009).

Rainwater harvesting has been practiced for more than 4, 000 years. It is necessary in areas having significant rainfall but lacking any kind of conventional, centralized government supply system, and also in areas where good quality fresh surface water or groundwater is lacking. (OAS, 2010).

Rain-water harvesting (RWH) technologies are a range of techniques used for collecting, storing and conserving rainfall and surface runoff in arid and semi-arid regions (Boers and Ben-Asher, 1982). RWH has come to mean the control or utilisation of rainwater close to the point rain reaches the earth. Rainwater harvesting (RWH) technologies are also aims at sustainable agriculture. According to Reijntjes et al. (1992) sustainable agriculture is farming that is ecologically sound, economically viable, socially just and acceptable. Sustainable agriculture aims to achieve permanence, which includes adopting technologies that 'maintain soil fertility indefinitely whilst utilising renewable resources that minimise environmental pollution' (Geier, 1999).

It is worth distinguishing, between the various types of RWH practised throughout the world. Its practice effectively divides into:

a) Storage of rain water on surface for future use.

b) Recharge to ground water. (UNESCO, 2000).

The application of an appropriate rainwater harvesting technology can make possible the utilization of rainwater as a valuable and, in many cases, necessary water resource.

An elaborate rainwater harvesting system for future rainwater storage purpose consists of three basic elements: a catchment/collection area, a conveyance system, and storage facilities. (OAS, 2010).

The collection area is the surface which directly receives the rainfall and provides water to the system. The collection area in most cases is the roof of a house or a building. The effective roof area and the material used in constructing the roof influence the efficiency of collection and the water quality. (OAS, 2010).

A conveyance system usually consists of gutters or pipes that deliver rainwater falling on the rooftop to cisterns or other storage vessels. Gutters are located around the edge of a sloping roof to collect and transport rainwater to the storage tanks. Gutters can be semi-circular or rectangular in shape and need to be supported so they do not sag or fall off when filled with water. Both drainpipes and roof surfaces should be constructed of chemically inert materials such as wood, plastic, aluminium, or fibreglass, in order to avoid adverse effects on water quality. (OAS, 2010).

The water ultimately is stored in a storage tank or cistern, which should also be constructed of an inert material. Reinforced concrete, fibreglass, or stainless steel are suitable materials.

Storage tanks may be constructed as part of the building, or may be built as a separate unit located some distance away from the building. (OAS, 2010).

All rainwater tank designs should include as a minimum requirement:

- A solid secure cover
- A coarse inlet filter
- An overflow pipe
- A manhole, sump and drain to facilitate cleaning
- An extraction system that does not contaminate the water; e.g. a tap
- A soakaway to prevent spilled water from forming puddles near the tank.

Additional features might include:

- A device to indicate the amount of water in the tank
- A sediment trap, tripping bucket or other 'foul flush' mechanism
- A lock on the tap
- A second sub-surface tank to provide water for livestock, etc

## 1.2 Statement of the Problem

The problems that dominate rainwater harvesting in household is poor and inefficient capturing and storing of rainwater for domestic use. Maintaining water supply, mastering advanced water technologies, securing supply and co-ordinating the efforts of existing water institutions are only some of the challenges facing water requirements for domestic purposes.

## 1.3 Objectives of the Study

i. To investigate the significance of household level rainwater harvesting as a strategy to adapt to rainfall variability and contribute to domestic water security in Kubwa Abuja.

ii. To determine the level of awareness and adoption of rain water harvesting techniques in the Kubwa area.

iii. To suggest possible ways of improving rain water harvesting technology to improve quality and quantity.

## 1.4 Justification of Study

Rain water harvesting has become a worldwide practice to meet the increasing demand for fresh water. In Nigeria it is widely practiced mostly in the southern part as the rainfall is widespread for over 8 months in a year. Rain water harvesting is practiced at individual level, household level, community level and occasionally at Local or State government level to augment the dwindling water supplies to urban centres.

The work is expected to contribute to the development of rainwater harvesting technology as a way of mitigating water scarcity which has become perennial problem over the years, which will eventually reduce the over dependence on ground water resource that is not readily available.

## 1.5 Scope of the Study

The scope of this project is limited to rainwater harvesting, storage and treatment for domestic purposes.

# CHAPTER TWO

## 2. LITERATURE REVIEW

Water is indispensable for any life system to exist on earth and is a very important component for the development of any society. The vitality of water can't be over-estimated. We depend on its good quality- and quantity- for domestic, agricultural purposes, industrial use amongst others.

Growing demands for water and the increasing costs of water are resulting in a need for countries to maximise the use of their existing water supplies and make use of their existing water supplies and make use of their hitherto unexploited freshwater resources. Numerous techniques, modern and traditional, for improving the use, and augmenting the availability of water resources have been developed and implemented in different parts of the world. These include among others Rainwater Harvesting, wastewater reuse and recycling and desalination. In many developing countries, the application of these technologies has been limited by lack of information on the approaches available and how well they work. (CAS 2000). Rainwater is water obtained from the rain. The water is formed into precipitation through a continuous cycle known as the water cycle.

The sun drives the water cycle; it heats water in the oceans. Some of the water evaporates as vapour into the air. Ice and snow can sublime directly into the water vapour. Rising currents take the vapour into the atmosphere, along with water from evapotranspiration, which is water transpired from plants and evaporated from the soil. The vapour rises into the air where cooler temperature causes it to condense into the clouds. Air currents move clouds around the globe; cloud particles collide, grow and fall out of the sky as precipitation. Most precipitation falls back into the oceans or onto land, where due to gravity, the precipitation flows over the ground as surface runoff. A portion of runoff enters rivers in valleys in the landscape, with streamflow moving water towards the oceans. Runoff and groundwater seepage accumulate and are stored as freshwater in lakes. Not all runoff flows into rivers. Much of it soaks into the ground as infiltration. Some water infiltrates deep into the ground and replenishes aquifers (saturated subsurface rock), which store huge amounts of freshwater for long periods of time. Some infiltration stays close to the land surface and can seep back into surface-water bodies (and the ocean) as groundwater discharge, and some groundwater finds openings in the land surface and emerges as freshwater springs. Over time, though all the water keeps moving, some to re-enter the Ocean to end/begin another cycle. (ga.water.usgs.gov/edu 2010).

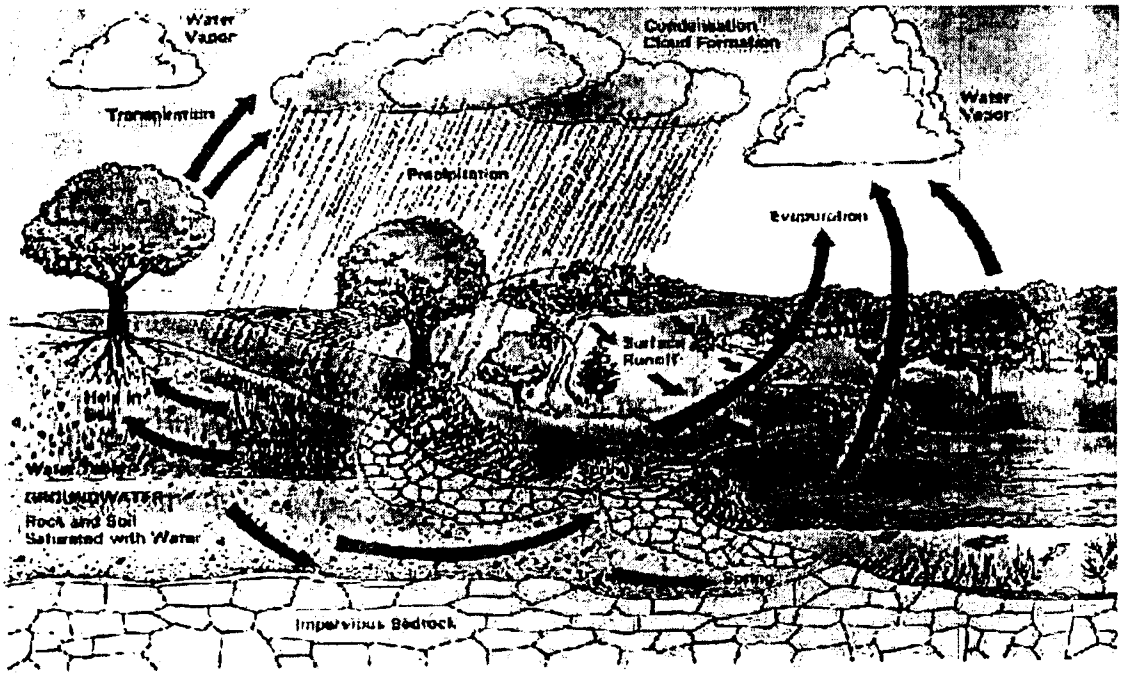

Fig 2.1 Water cycle (ga.water.usgs.gov. 2010)

## 2.1 Precipitation

Precipitation is any form of water that falls on the earth's surface. Different forms of precipitation include drizzle, rain, hail, snow, sleet and freezing rain.

Rain is a precipitation that falls to the earth in drops of 5mm or more in diameter. Raindrops forms when millions of tiny water droplets collide together in clouds to form larger ones. Eventually, they become too heavy and fall out of the clouds as rain. (Wikipedia. 2010).

Drizzle is light precipitation that is made up of liquid water drops that are smaller than rain drop. Due to its small size, much of the drizzle evaporates before falling to the ground. (windows2universe, 2010)

Hail is a form of solid precipitation which consists of balls or irregular lumps of ice, that are individually called hail stones. Hailstones on Earth consist mostly of water ice and measures between 5mm and 150mm in diameter. (Wikipedia, 2010).

Snow is a type of precipitation in which the water falls as ice crystals or combinations of many ice crystals, called snowflakes. Snowflakes form in clouds where the temperature is below freezing (0°c, or 32°F). As the snow crystals grow they become heavier and fall towards earth. (windows2universe, 2010)

Sleet forms when a partially melted snowflake or raindrop turns back into ice as it is falling through the air. Sleet is usually tiny clear ice pellets that bounce when they hit the ground. An ice pellet is about 5mm or less, which is smaller than hail.

Freezing rain happens when raindrops fall in liquid form and immediately freeze as they hit a cold surface. The process for freezing rain is similar to the process for sleet, except that freezing rain goes through a deeper layer of above freezing temperatures, allowing the snowflake to melt even further. (Wikipedia, 2010).

## 2.2 Rainwater Harvesting (RWH)

Water harvesting in its broadest sense can be defined as the collection of run-off rainwater for domestic water supply, agriculture and environmental management. Rainwater harvesting is one of the promising ways of supplementing the surface and underground scarce water resources in areas where existing water supply system is inadequate to meet demand. (Gould, 2000).

Rainwater harvesting (RWH) primarily consists of the collection, storage and subsequent use of captured rainwater as either the principal or as a supplementary source of water. Both potable and non-potable applications are possible (Fewkes, 2006). Examples exist of systems that provide water for domestic, commercial, institutional and industrial purposes as well as agriculture, livestock, groundwater recharge, flood control, process water and as an emergency supply for fire fighting (Gould & Nissen-Peterson,1999; Konig, 2001; Datar, 2006). The concept of RWH is both simple and ancient and systems can vary from small and basic, such as the attachment of a water butt to a rainwater downspout, to large and complex, such as those that collect water from many hectares and serve large numbers of people (Leggett *et al*, 2001a). Before the latter half of the twentieth century, RWH systems were used predominantly in areas lacking alternative forms of water supply, such as coral islands (Krishna, 1989) and remote, arid locations lacking suitable surface or groundwater resources (Perrens, 1975).

Rainwater harvesting has been practiced for more than 4, 000 years, and, in most developing countries, is becoming essential owing to the temporal and spatial variability of rainfall. (Gould 1990). As water harvesting is an ancient tradition and has been used for millennia in most drylands of the world, many different techniques have been developed. However, the same techniques sometimes have different names in different regions and others have similar names but, in practice, are completely different (Oweis 2004). Consequently, there are a dozen of different definitions and classifications of water harvesting techniques and the terminology used at the regional and international levels has not yet been standardized (Nasr 1999).

Hiterndra *et al.* (2008) defined RWH as the collection, storage and use of rainwater for small-scale productive purposes. Critchley(1991) defined it as the collection of runoff for productive use. Oweis (2004) defined it as the concentration of rainwater through runoff into smaller target areas for beneficial use. Mati *et al.* (2006) defined RWH as the deliberate collection of rainwater from a surface known as catchment and its storage in physical structures or within the soil profile. Sivanappan, (1997) defines it as the collection and storage of any form of water either runoff or creek flow for domestic and irrigation use. Boers *et al.* (1982) defined it as a range of techniques used for collecting, storing and conserving rainfall and surface runoff in arid and semi-arid regions. These techniques are all aimed at achieving sustainable agriculture or domestic water availability. According to Reijntjes *et al.* (1992), sustainable agriculture is farming that is ecologically sound, economically viable, socially just and acceptable. Sustainable agriculture aims to achieve *permanence*, which includes adopting technologies that 'maintain soil fertility indefinitely whilst utilising renewable resources that minimise environmental pollution'. (Geier, 1999).

In its broadest sense, is a technology used for collecting and storing rainwater for human use from rooftops, land surfaces or rock catchments using simple techniques such as jars and pots as well as engineered techniques.

Rainwater harvesting is a simple and low cost technique that involves the capture and storage of rainwater from roofs and ground catchments for domestic, agricultural, industrial and environmental purposes. It has many advantages in rapidly growing cities and under future climate change scenarios. (Clemete, R.S.*et.al* 2003). Rainwater harvesting is necessary in areas having significant rainfall but lacking any kind of conventional, centralized government supply system, and also in areas where good quality fresh surface water or groundwater is lacking. (Gould, 1990).

A rainwater harvesting system consists of: the supply (rainfall), the demand (water needed by domestic and agricultural activities) and a system for collecting water and moving it to areas where it is needed.

Besides giving dry areas or cities the water needed to sustain a population, rainwater harvesting systems also have other advantages, including those listed below.

- A proper rainwater harvesting system can reduce costs because it effectively reduces water usage.
- Collecting rainwater in a huge catchment system prevents erosion and minimizes the downstream impact of bodies of water, which in turn, can help prevent floods.
- These systems help reduce water consumption from cities' main sources, thereby also reducing the use of pumps, electricity and energy. Another result of this is lower carbon emissions and pollution levels.
- Using rainwater also reduces the demand and the pollution on rivers and groundwater. Studies show that 86% of a regular household's water needs can be supplied solely by rainwater, even without purification or treatment.
- Rainwater has been proven to be great for washing clothes since it is soft water and doesn't leave residue or lime scale. It is also better for plants since it is all natural and does not contain chemicals.
- Rainwater collection and storage can also reduce the impacts of drought, storm water runoff and peak flow levels as well as reliance on ground and surface water, also lower nonpoint source pollution, allow groundwater to recharge and promote water

conservation and sustainable practices (LaBranche et al., 2007; Hicks, 2008). Rainwater harvesting (RWH) can improve agricultural production by making water available during the time of dry spells.

- Rainwater harvesting can be practiced to provide water for irrigation, domestic water and water for livestock. It can also serve as a way to replenish groundwater.

Rainwater harvesting can enhance the water availability at any specified location and time, increase groundwater levels and improve groundwater ecosystems. In addition, rainwater harvesting reduces floods and soil erosion. Therefore, rainwater harvesting yields numerous social and economic benefits, and contributes to poverty alleviation and sustainable development. (IGES, 2009).

It is worth bearing in mind that rainwater harvesting is not the definitive answer to household/Domestic, Irrigation and Industrial water problems. There is a complex set of inter-related circumstances that have to be considered when choosing the appropriate water source. These include cost, climate, hydrology, social and political elements, as well as technology, all play a role in the eventual choice of water supply scheme that is adopted for a given situation. RWH is only one possible choice, but one that is often overlooked by planners, engineers and builders.

The reason that RWH is rarely considered is often due to lack of information – both technical and otherwise. In many areas where RWH has been introduced as part of a wider drinking water supply programme, it was at first unpopular, simply because little was known about the technology by the beneficiaries. In most of these cases, the technology has quickly gained popularity as the user realises the benefits of a clean, reliable water source at the home. the town supply is unreliable or where local water sources dry up for a part of the year, but is also In many cases RWH has been introduced as part of an integrated water supply system, where often used as the sole water source for a community or household. It is a technology that is flexible and adaptable to a very wide variety of conditions, being used in the richest and the poorest societies on our planet, and in the wettest and the driest regions of the world.

The identification of potential areas suitable for RWH is therefore the key for a successful RWH intervention. One of the main reasons for failure of RWH structures is the lack of scientifically verified information which could be used to identify areas where RWH can be applied and for which type of RWH techniques.

The potential of areas for RWH depends on a multitude of parameters, either physical factors like rainfall, land use, soil and topography and/or the combination of the physical factors and socio-economic factors.

Kahinda *et al.* (2008) lists six key factors to be considered when identifying RWH sites: climate (rainfall), hydrology (rainfall–runoff relationship and intermittent watercourses), topography (slope), agronomy (crop characteristics), soils (texture, structure and depth) and socio-economic (population density, work force, people's priority, experience with RWH, land tenure, water laws, accessibility and related costs). Rao *et al.* (2003) use land use, soil, slope, runoff potential, and proximity to the utility points (like irrigation and drinking water supply schemes), geology, and drainage as criteria to identify suitable sites for RWH.

It is worth distinguishing, between the various types of RWH practised throughout the world. Its practice effectively divides into:

1. Storage of rain water on surface for future use.
2. Recharge to ground water. (UNESCO 2000).

### 2.2.1 Storage of rainwater for future use

The system basically involves collecting the water that falls on the zinc, asbestos, or tile roof of a house during rainstorms, and conveying it by an aluminium, PVC, wood or plastic drain or collector to a nearby storage unit or Cistern (tank). The success of rainwater harvesting systems depends on

(i) The quantity and quality of other water sources available;

(ii) The size of household and per capita water demand;

(iii) Financial condition

#### 2.2.1.1. Rainwater collection systems

Commonly used systems for storage of rain water for future use are constructed of three principal components; namely, the catchment/collection area, the conveyance system, and storage facilities. (O.A.S, 2010).

##### 2.2.1.1.1. Catchment area

Rainfall is directly received on this surface and from here delivered to the system. It could either be a Rooftop Catchment or Land Surface Catchment.

Rainwater can be collected from most form of roof. In the most basic form of this technology, rainwater is collected in simple vessels at the edge of the roof. Variations on this basic approach include collection of rainwater in gutters which drain to the collection vessel through down-pipes constructed for this purpose, and/or the diversion of rainwater from the gutters to containers for settling particulates before being conveyed to the storage container for the domestic use.

As the rooftop is the main catchment area, the amount and quality of rainwater collected depends on the area and type of roofing material. Reasonably pure rainwater can be collected from roofs constructed with galvanized corrugated iron, aluminium or asbestos cement sheets, tiles and slates, although thatched roofs tied with bamboo gutters and laid in proper slopes can produce almost the same amount of runoff less expensively. However, the bamboo roofs are least suitable because of possible health hazards. Similarly, roofs with metallic paint or other coatings are not recommended as they may impart tastes or colour to the collected water. Roof catchments should also be cleaned regularly to remove dust, leaves and bird droppings so as to maintain the quality of the product water. (Gould, 1992).

Care must be taken, however, to check water quality parameters if the water is to be used for drinking purposes, as lead and zinc contamination from corrugated iron roofs can be higher than allowed by drinking water standards (OAS 2010).

Rainwater harvesting using ground or land surface catchment areas is less complex way of collecting rainwater. It involves improving runoff capacity of the land surface through various techniques including collection of runoff with drain pipes and storage of collected water. Compared to rooftop catchment techniques, ground catchment techniques provide more opportunity for collecting water from a larger surface area. By retaining the flows (including flood flows) of small creeks and streams in small storage reservoirs (on surface or underground) created by low cost (e.g. earthen) dams, this technology can meet water demands during dry periods. There is a possibility of high rates of water loss due to infiltration into the ground, and, because of the often marginal quality of the water collected, this technique is mainly suitable for storing water for agricultural purposes. Various techniques available for increasing the runoff within ground catchment areas involve:

i) Clearing or altering vegetation cover.

Clearing vegetation from the ground can increase surface runoff but also can induce more soil erosion. Use of dense vegetation cover such as grass is usually suggested as it helps to both maintain a high rate of runoff and minimize soil erosion.

ii) Increasing the land slope with artificial ground cover.

Steeper slopes can allow rapid runoff of rainfall to the collector. However, the rate of runoff has to be controlled to minimise soil erosion from the catchment field. Use of plastic sheets, asphalt or tiles along with slope can further increase efficiency by reducing both evaporative losses and soil erosion. The use of flat sheets of galvanized iron with timber frames to prevent corrosion was recommended and constructed in the State of Victoria, Australia, about 65 years ago (Kenyon, 1929; cited in UNEP, 1982).

iii) Reducing soil permeability by the soil compaction and application of chemicals.

This involves smoothing and compacting of soil surface using equipment such as graders and rollers. To increase the surface runoff and minimize soil erosion rates, conservation bench terraces are constructed along a slope perpendicular to runoff flow. The bench terraces are separated by the sloping collectors and provision is made for distributing the runoff evenly across the field strips as sheet flow. Excess flows are routed to a lower collector and stored (UNEP, 1982).

In addition to clearing, shaping and compacting a catchment area, chemical applications with such soil treatments as sodium can significantly reduce the soil permeability. Use of aqueous solutions of a silicone-water repellent is another technique for enhancing soil compaction technologies. Though soil permeability can be reduced through chemical treatments, soil compaction can induce greater rates of soil erosion and may be expensive. Use of sodium-based chemicals may increase the salt content in the collected water, which may not be suitable both for drinking and irrigation purposes.

### 2.2.1.2 Conveyance

Conveyance systems are required to transfer the rainwater collected on the rooftops to the storage tanks. This is usually accomplished by making connections to one or more down-pipes connected to the rooftop gutters.

When selecting a conveyance system, consideration should be given to the fact that, when it first starts to rain, dirt and debris from the rooftop and gutters (as a result of dry periods, become contaminated with a variety of pollutants such as atmospheric particulates, bird droppings, leaves and other debris (Cunliffe, 1998) will be washed into the down-pipe. Thus, the relatively clean water will only be available some time later in the storm. There are several possible choices to selectively collect clean water for the storage tanks. The most common is the down-pipe flap. With this flap it is possible to direct the first flush of water flow through the down-pipe, while later rainfall is diverted into a storage tank. When it starts to rain, the flap is left in the closed position, directing water to the down-pipe, and, later, opened when relatively clean water can be collected. A great disadvantage of using this type of conveyance control system is the necessity to observe the runoff quality and manually operate the flap. An alternative approach would be to automate the opening of the flap as described below.

A funnel-shaped insert is integrated into the down-pipe system. Because the upper edge of the funnel is not in direct contact with the sides of the down-pipe, and a small gap exists between the down-pipe walls and the funnel, water is free to flow both around the funnel and through the funnel. When it first starts to rain, the volume of water passing down the pipe is small, and the 'dirty' water runs down the walls of the pipe, around the funnel and is discharged to the ground as is normally the case with rainwater guttering. However, as the rainfall continues, the volume of water increases and 'clean' water fills the down-pipe. At this higher volume, the funnel collects the clean water and redirects it to a storage tank. The pipes used for the collection of rainwater, wherever possible, should be made of plastic, PVC or other inert substance, as the pH of rainwater can be low (acidic) and could cause corrosion, and mobilization of metals, in metal pipes. (OAS, 2010).

In order to safely fill a rainwater storage tank, it is necessary to make sure that excess water can overflow, and that blockages in the pipes or dirt in the water do not cause damage or contamination of the water supply. The design of the funnel system, with the drain-pipe being larger than the rainwater tank feed-pipe, helps to ensure that the water supply is protected by allowing excess water to bypass the storage tank. In this system, it also is possible to fill the tank from a municipal drinking water source, so that even during a prolonged drought the tank can be kept full. Care should be taken, however, to ensure that rainwater does not enter the drinking water distribution system.

### 2.2.1.3 Collection Devices

Storage tanks for collecting rainwater harvested using guttering may be either above or below the ground. Precautions required in the use of storage tanks include provision of an adequate enclosure to minimise contamination from human, animal or other environmental contaminants, and a tight cover to prevent algal growth and the breeding of mosquitoes. Open containers are not recommended for collecting water for drinking purposes. Various types of rainwater storage facilities can be found in practice. Among them are cylindrical Ferro-cement tanks and mortar jars.

The storage capacity needed should be calculated to take into consideration the length of any dry spells, the amount of rainfall, and the per capita water consumption rate.

Storage tanks, usually the most expensive component of the rainwater harvesting system, come in a wide variety of sizes and types (Pushard, 2008). When deciding on the type of tank to use, the main factors to consider include where you live and your budget. When choosing the size of storage tank or cistern, consider several variables: rainwater supply (local precipitation), demand, projected length of dry spells without rain, catchment surface area, aesthetics, personal preference and monetary budget.

Tanks can be above or below ground. Factors such as soil, outside temperature ranges and cost should be used to determine whether a tank is placed above or below ground. Some tanks are suited for above-ground placement (i.e. vinyl-lined swimming pools), where others can be used both above and below ground (i.e. polyethylene). Some types of tanks are built to be buried (i.e. polyethylene tanks designed for burial). (Pushard, 2008).

Below is a general overview of some tank types and characteristics

i. Tanks should be easy to access and maintain

ii. Tanks should be opaque or darker to inhibit algae growth

iii. For Potable systems, storage tanks must never have been used to store toxic materials.

iv. Tanks must be covered and vents screened to discourage mosquito breeding

v. Tanks used for potable system must be accessible for cleaning.

vi. Install first-flush and screening devices prior to water reaching the tanks to keep it as fresh and clean as possible.

vii. Keep tops of tanks free of debris to make it harder for animals to reach the top ot the tank.

viii. Buried tanks should be located in well-drained soil and location.

ix. Plan where storage tank overflow should be piped or directed to. Keep it away from underneath the holding tank to prevent pad erosion and to keep animals away.

#### 2.2.1.3.1. Fiberglass

Fiberglass tanks are light weight, reasonably priced and long lasting. Fibreglass is durable and can be repaired easily. They are built in standard capacities from small 50gallons to 15000gallons (220l to 70000l) and can be laid as a vertical cylinder or low-horizontal cylinder configurations. The tank should be opaque to inhibit algae growth. (Pushard, 2008).

#### 2.2.1.3.2. Polyethylene

Polyethylene tanks are probably the most common type of tank being sold today and are readily available at most homes, farms, establishments etc. (Pushard, 2008). They vary greatly in size, shape and colour and can be used above or below ground. Most of the tanks stocked by farm and garden houses are usually for above-ground installations. For buried installed installation, specially designed and reinforced tanks are necessary to withstand soil expansion and contraction. (Pushard, 2008).

Polyethylene tanks are comparatively inexpensive, lightweight and long-lasting and are available in capacities from 50 gallon barrels to 10000 gallons (220l-45000l). They are lighter in weight than other types of tanks, including fibreglass and consequently are cheaper and easier to transport.

Polyethylene tanks tend not to retain paint well (Pushard, 2008), so the use of pre-painted (i.e. pigmented) tanks manufactured with opaque plastic is advised. Black and dark coloured will absorb heat and thus, should be shaded or buried.

Polyethylene tanks should be checked occasionally for leakage. (Pushard, 2008).

### 2.2.1.3.3. In-ground polyethylene

In-ground polyethylene tanks are more costly for two reasons: the cost of excavation and the cost of a more heavily reinforced tank. The latter is required if the tank is to be buried more than two feet deep. Burying a tank in soil with high clay content is not recommended because of the expansion and contraction cycles of clay.

For below ground installation, the walls of poly tanks must be manufactured thicker and sometimes, an interior bracing structure must be added. (Pushard, 2008).

### 2.2.1.3.4. Swimming pools

Above ground swimming pools are commonly used for rainwater catchment. A few of the issues related to pools as storage devices are

- The pool liner typically only goes up to the lip of the pool and slips into the pool.
- Liners are not food grade quality and may in fact be made to retard bacterial growth in the pool and can be toxic
- Large diameters of these pools are not easily covered and therefore it is difficult to keep out debris and animals.

However, swimming pools are very inexpensive, readily available and as easy to install solution. If this is the only available option then the following precautions have to be taken:

- Make sure the liner is one made for storing and holding water.
- Plan to have a support system (i.e. a post in the middle of the pool) to hold up the cover so that it does not sag into the water.

- Make sure the cover can be firmly attached to the top of the pool to keep out unwanted guests and debris. (OAS, 2010).

### 2.2.1.3.5 Metal

As with wood, galvanised sheet metal tanks can also be an attractive option. They are available in sizes ranging from small tanks of 150 gallons to medium-sized 2500 gallon tanks and are lightweight and easy to relocate if required. Most tanks are corrugated galvanised steel dipped in hot zinc to improve corrosion resistance. These tanks should be lined with a food-grade liner, usually polyethylene or PVC or coated on the inside with epoxy paint. The paint or liner will extend the life of the metal and, if being used for potable water, must meet approved quality standard for potable water use. (Pushard, 2008).

These tanks are for above-ground use. Old or recycled tanks may contain lead and should be avoided. Brass and Bronze fittings should not be connected directly to the tank as they will cause corrosion. Additionally, care should be taken when cleaning these tanks, as a film develops naturally on the inside of the tank, which coats the tank and inhibits corrosion. (OAS, 2010).

### 2.2.1.3.6 Concrete

The most versatile of tanks, concrete tanks can either be poured in place or prefabricated. They can either be constructed above or below ground. They can be owner or contractor-built. Poured-in-place tanks can be very attractive and easily integrated into new construction. For example, the tank can be placed under a patio or a basement. Concrete tanks once poured are considered permanent.

One unique advantage of poured concrete is that the concrete will over time decrease the corrosiveness of rainwater by leaching into the water. This advantage of concrete tanks results in a desirable taste imparted to the water by calcium in the concrete being dissolved in locations where there is slightly acidic rainwater. For Potable systems, it is essential that the interior of the tank be plastered with a high-quality material approved for potable use.

Underground concrete tanks are prone to cracking and leaking, especially when in clay soil. Leaks can easily be repaired, although the tank may need to be drained to make the repair. If building the tank, it is recommended to involve the expertise of a structural engineer to determine the size and spacing of reinforcing steel to match the structural loads of a poured-in-place concrete. (Pushard, 2008).

#### 2.2.1.3.7 Ferrocement

Ferrocement is the term used to describe a steel and mortar composite material. These tanks can be above or below ground and can be done by contractors or homeowners. They are listed separately from concrete, not just because of the material s used to construct them, but also because they have different problems and advantages. The ferrocement tank consists of a lightly reinforced concrete base on which is erected a circular vertical cylinder with a 10 mm steel base.

These tanks are typically built with concrete, but have multiple layers of wire mesh – typically chicken wire-wrapped around a light framework of rebar, embedded in the concrete. Walls can be as thin as 1 inch and still be strong. Consequently, it can cost less to build than a concrete-only tank. If a ferrocement tank is to be bought, it should be ensured that it doesn't contain any toxic compounds in the concrete and that the wires are not visible on the inside of the tank. (Pushard, 2008).

Ferrocement, like concrete, will need maintenance and repair as cracks appear. It is important to ensure to ensure that the ferrocement mix does not contain any toxic components. Some sources recommend painting above-ground tanks white to reflect the sun's rays, reduce evaporation, and keep the water cool. (WaterAid, 2009).

### 2.2.1.3.8 Stone and Mason

Handmade stone or mason tanks are not as common as they once were. Increasing labour costs, decreasing costs and increasing availability of other types of tanks has limited their use to areas where labour is very cheap or where budget is not an issue.

The mass of the stone gives these tanks two distinct advantages: it keeps the water cool in hot climates and they can be very attractive. As with ferrocement tanks, care should be taken to make sure the mix does not contain toxic materials.

These tanks are custom-built, so they can be as large as designed. Most tanks are designed to be circular, since this shape is more structurally sound. These tanks, if properly constructed and maintained will last for decades. (Pushard, 2008).

### 2.2.1.3.9 Plastered tire cisterns

Another type of hand-made tanks is plastered tire cisterns. They are simply a circle of buried tires with a wire mesh inside covered with plaster. Just like stone or cement cisterns, they will need periodic maintenance to repair cracks on the inside.

These tanks are meant to be buried and can be very economical for large tank sizes (i.e. 10000+ gallons/37900 litres) especially if owner-built. In earthships, tanks are typically built as an integral part of the home and can provide cooling in hot climate. In cooler climates, the tops and sides should be insulated to prevent cooling. Care should be taken in building a plastered tie cistern to ensure the wire mesh and tires are thoroughly covered with plaster.

As with stone and mason cisterns, these tanks are custom-built, so they can be as large as designed. They are typically designed to be circular but since they can be almost any shape. These tanks, if properly constructed and maintained, will last decades. (Pushard, 2008).

### 2.2.2. Recharge to Groundwater

Artificial recharge is the planned, human activity of augmenting the amount of groundwater available through works designed to increase the natural replenishment or percolation of surface waters into the groundwater aquifers, resulting in a corresponding increase in the amount of groundwater available for abstraction. (UNEP, 2010). Although artificial recharging is primarily used to preserve or enhance groundwater resources, it has been used for many other beneficial purposes such as conservation of surface runoff and disposal of flood waters, control of salt water intrusion, storage of water to reduce pumping and piping costs, temporary regulation of ground water abstraction, and water quality improvement by removal of suspended solids by filtration through the ground or by dilution by mixing with naturally occurring groundwater (Asano, 1985). The other areas of use of artificial recharge are in wastewater disposal, waste treatment, secondary oil recovery, prevention of land subsidence, and storage of fresh water with saline aquifers, crop development and stream flow augmentation (Oaksford, 1985).

Rainwater is the primary source of water for recharging groundwater. The recharge process either occurs naturally or can be done artificially using a variety of methods. As the natural land cover is transformed to give way for other landuse types, the natural recharge process is affected and if not check could result in the depletion of groundwater. (UNDP, 2007).

Recharge to ground water is a new concept of rain water harvesting. Rainwater is allowed to replenish the aquifer. America Ground water trust (2008) describes the Aquifer as a sub-surface geologic formation(s) (solid rock and/or unconsolidated sediments) that contains ground water in sufficient quantities to be used, or have the potential to be used, for drinking water supply or for commercial, industrial or agricultural purposes.

Aquifer can get recharged in two ways naturally and artificially. In natural recharge, rainwater and surface water get percolated into shallow or deep aquifer by itself through uncovered soil surface or fissures on the rock mass. Any man-made scheme or facility that adds water to an aquifer may be considered to be an artificial recharge system. (Moegiadi 2002). Artificial recharge to ground water is a process by which the ground water reservoir is augmented at a rate exceeding that obtaining under natural conditions of replenishment. In artificial recharge, water is percolated using different methods to recharge shallow aquifer. (Hiterndra Raj Joshi. *et al* 2008).

Artificial recharge techniques are adopted where:-

- Adequate space for surface storage is not available especially in urban areas.
- Water level is deep enough (> 8 m.) and adequate subsurface storage is available.
- Permeable strata are available at shallow / moderate depth.
- Where adequate quantity of surface water is available for recharge to ground water.
- Ground water quality is bad and our aim is to improve it.
- Where there is possibility of intrusion of saline water especially in coastal areas.
- Where the evaporation rate is very high from surface water bodies.

In other areas, rain water harvesting techniques may be adopted. (UNESCO, 2000).

The following are structures generally used for artificial Groundwater recharge.

### 2.2.2.1 Pits

Recharge pits are constructed for recharging the shallow aquifers. These are constructed 1 to 2 m. wide and 2 to 3 m. deep which are back filled with boulders, gravels & coarse sand. This design is suitable for areas with shallow water level in hard rock as well as soft rock areas for individual houses, group housing societies, schools and small industrial set ups. (UNDP. 2007).

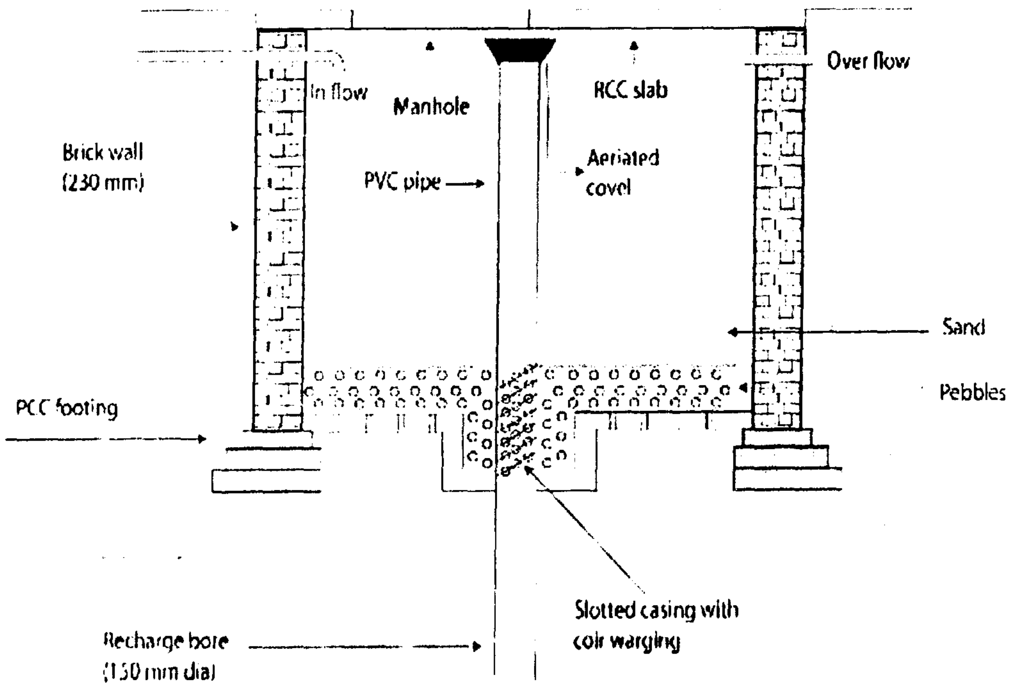

Fig 2.2 Recharge pit for shallow water tables (UNDP, 2007)

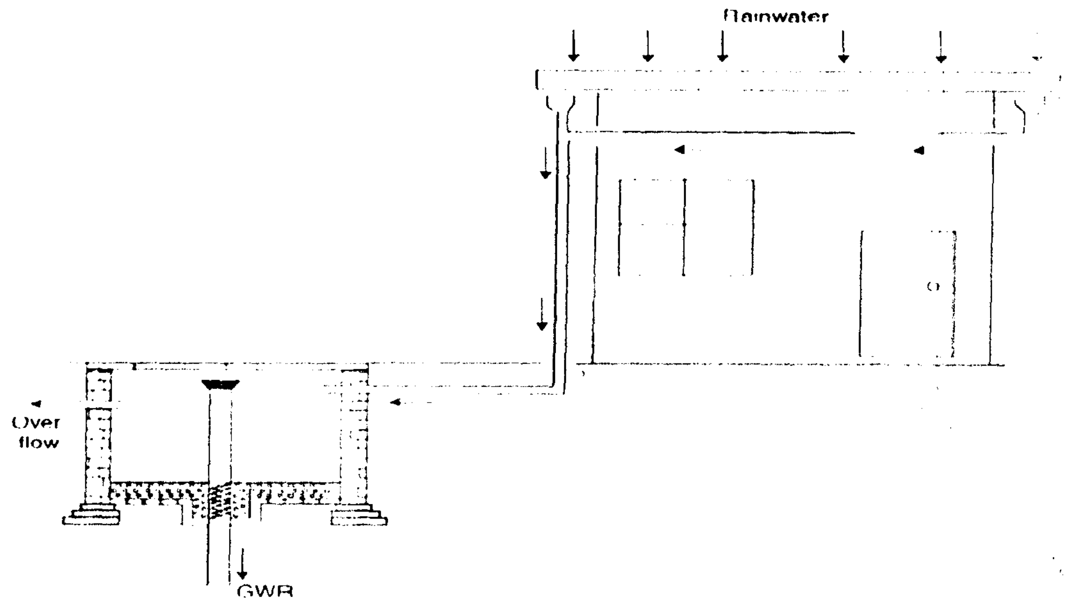

Fig 2.3 Groundwater recharge well with Rooftop Catchment (UNDP, 2007)

### 2.2.2.2Trenches

These are constructed when the permeable strata is available at shallow depths. Trench may be 0.5 to 1 m. wide, 1 to 1.5 m. deep and 10 to 20 m. long depending upon availability of water. These are back filled with filter materials.

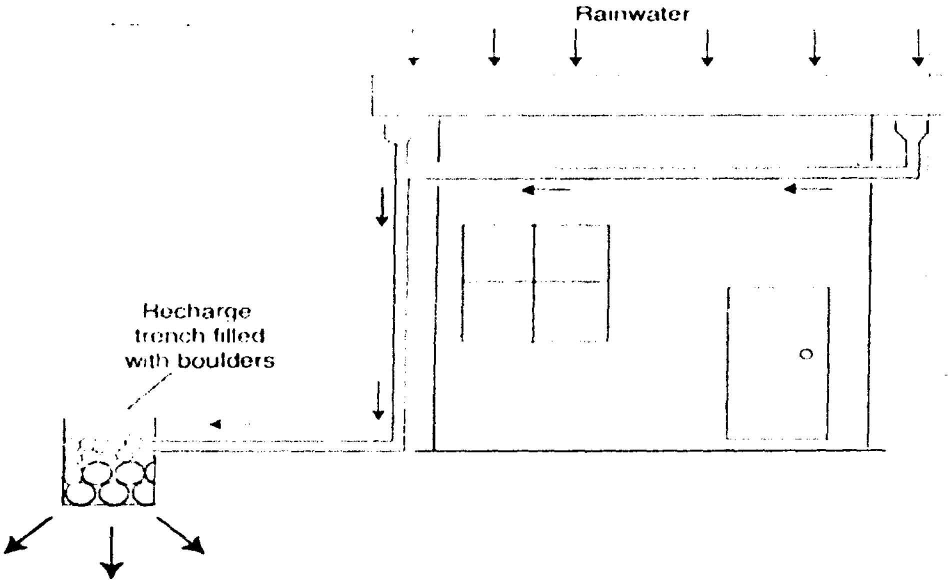

Fig 2.4 Groundwater recharge using trench filled with boulders (UNDP, 2007)

This design is suitable for areas with shallow water level in hard rock as well as soft rock areas for large group housing societies, schools and small industrial sheds. (UNDP, 2007)

### 2.2.2.3 Dug wells

Existing dug wells may be utilised as recharge structure and water should pass through filter media before putting into dug well.

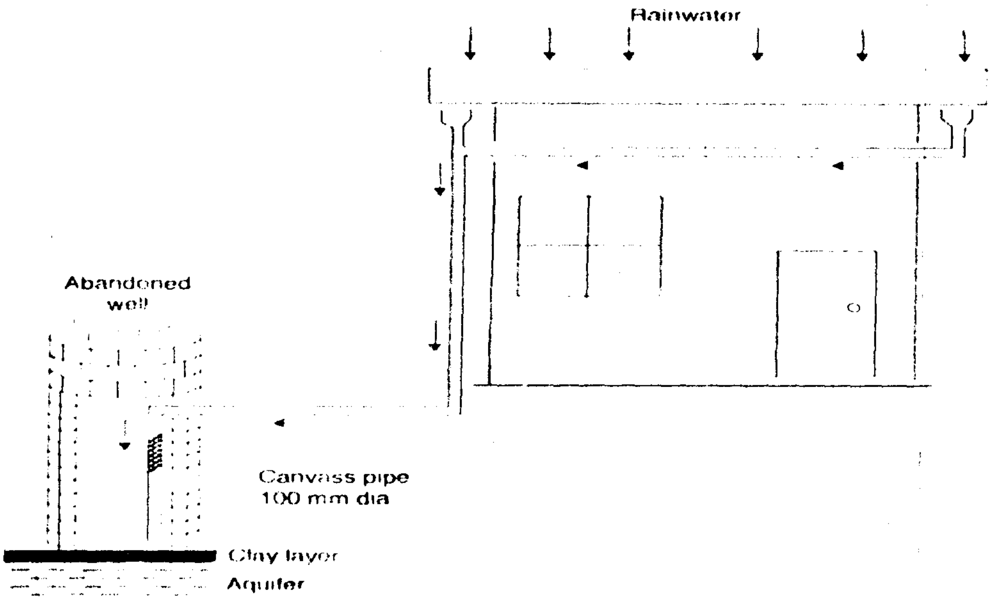

Fig 2.5 Dug out wells used as recharge facility (UNDP, 2007)

This design is suitable for areas with shallow (5 to 15 m) water level in hard rock as well as soft rock terrain for individual houses, group housing societies, schools and small industrial sheds. (UNDP, 2007).

### 2.2.2.4 Hand pumps

The existing hand pumps may be used for recharging the shallow/deep aquifers, if the availability of water is limited. Water should pass through filter media before diverting it into hand pumps. This design is suitable for areas with moderate to deep water level in both hard

Industrial zone), Mpape, Karimu, Gwagwa, Dei-Dei (housing the International Livestock Market and also the International Building Materials market).

Agriculture in FCT produces yams, millet, maize, sorghum and Beans. Mineral resources include clay, tin, feldspar, gold, iron ore, lead, marble and talc.

The largest indigenous group in Abuja are the Gbabyi (also known as the Gwari). The next largest indigenous group are the Koro. Smaller indigenous groups also inhabit the area, such as the Gade, Egbura, Gwandara, Bassa and the Gana gana.

The FCT is divided into six area councils namely, Abuja Municipal, Gwagwalada, Abaji, Kuje, Bwari and Kwali. (ngex.com, 2010).

## 3.2 METHODOLOGY

The basic tool for data collection was structured questionnaires. The questionnaire was framed in such a way to meet up with the objectives of this study. Based on the literature review and on several qualitative interviews from households conducted prior to the design of the questionnaire, the following five categories of variables were described in composing the questionnaire:

- description of household and education,;
- access to water
- perceived quality of service;
- storage practices;
- Willingness to use the alternative system.

# CHAPTER FOUR

## 4. RESULTS AND DISCUSSION

During the process of collecting data for this research work on the rainwater harvesting, storage and treatment for domestic purposes in Kubwa, there are factors that inhibit the level of bias of the respondents and these are:

- **Illiteracy**: As a result of illiteracy of some people in rural area or people who are academically illiterate, effective communication is difficult, especially in the case where these respondents cannot read or write in English language so effort have to be made in translating the question to him/her.
- **Suspicious from the side of the respondents**: There is always a question from the respondent that why are we asking such questions and this can eventually lead to wrong information such as thinking that we are from the government that it might have something to do with tax increment.
- **Secrecy**: There are prejudices against certain questions that are often faced by researchers because people feel that their privacy is intruded into e.g. the number of children.
- Some respondents falsify information in other not to be looked down upon because they are seeing those administering the questionnaire as people from cities so by giving the right information they will think they are socially inferior.

The field quantitative data were interpreted with the use of the descriptive statistics e.g. percentage, bar and pie charts to show the relationship between the rainwater harvesting and socio-economic variables such as family sizes, education, and water conservation and storage and further to test the effect of education on the people's perception of rainwater harvesting, water quality, and conservation of household water.

## 4.1 Analysis of socio-demographic data

### 4.1.1 The Respondent

#### 4.1.1.1 Education

This was asked to determine the educational level of the respondents. This question was open to all respondents. Most of the respondents interviewed (Fifty percent (50%)) of the respondents studied to a tertiary level while forty percent (40%) have received up to a secondary education. Three percent (3%) have primary school qualification while the other four percent (4%) are technically inclined. Three percent (3%) refused to comment on their educational status.

Table 4.1 Educational Level of Respondents

| **Level** | **Frequency** | **Percentage (%)** |
|---|---|---|
| Primary | 6 | 3 |
| Secondary | 80 | 40 |
| Tertiary | 100 | 50 |
| Others | 8 | 4 |
| No response | 6 | 3 |

#### 4.1.1.2 Family Size

This was asked to determine the number of people in the respondent's household as this could have an influence on the quantity of water required by the household.

This question was open to all respondents though 2.5% refused to comment on their family size. Seven percent (7%) of the respondents had a family size ranging from 1 to 2 family members. 43.5% had a size of greater than 2 but less than 5. Most respondents have a family size of 5-6 people. 8.5% had size 7 to 10 persons.

Table 4.2 Size of Family

| Family Size | Frequency | Percentage (%) |
|---|---|---|
| 1-2 | 9 | 7 |
| 3-4 | 41 | 41 |
| 5-6 | 43 | 43.5 |
| 7-10 | 9 | 8.5 |
| >10 | 5 | 2.5 |
| No response | 5 | 2.5 |

### 4.2 Households' opinion on rainwater harvesting

All respondents interviewed knew to a certain extent of simple rainwater harvesting techniques either from direct observation, water conservation practice or Extension Agents etc. This question was asked to determine the level of involvement of the household in Rainwater collection. Options given were 'Yes' and 'No'.

Fifty percent (50%) of the respondents admitted to partaking in the collection of rainwater since they moved to the Kubwa while the rest have not partaken in Rainwater collection in recent times. This question was open to all respondents.

### 4.2.1 Reason for collection of rainwater

This question was open to only respondents that harvested rainwater since they only would have a reason to collect rainwater.

Eighty six percent (86%) of the respondent who collect rainwater restricted its use to certain domestic purposes e.g. bathing, washing, flushing of toilet etc. About Three percent (3%) harvest rainwater for small scale irrigation. Eleven percent (11%) of the respondents harvested rainwater for their commercial ventures.

Table 4.3 Reason for Rainwater Collection

| **Reason for rainwater collection** | **Frequency** | **Percentage (%)** |
|---|---|---|
| Domestic Purposes | 86 | 86 |
| Irrigation Purposes | 3 | 3 |
| Other Purposes | 11 | 11 |

### 4.2.2 Condition that necessitated harvesting

Eighty-three percent (83%) of the respondents that collect rainwater attributed their collection to unreliability/inaccessibility of the Public water supply to satisfy their domestic needs. About Six percent (6%) attributed their collection to diminishing returns from the wells. Twelve percent (11%) of the respondents ticked 'Other factors'. Most of the respondents that

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This question was open to only respondents that harvested rainwater.

Table 4.4 Condition that necessitated collection

| Condition that necessitated Harvest | Frequency | Percentage (%) |
|---|---|---|
| Unreliability of Public Supply | 83 | 83 |
| Diminishing Groundwater Level | 6 | 6 |
| Other Factors | 11 | 11 |

### 4.2.3 Influence to harvest rainwater

Eighty-three percent (83%) reported to have been influenced by observation from practice by friends, neighbours, business associates etc. Three percent (3%) were influenced by extension agents while Fourteen percent (14%) specified that it was logical to them to harvest as they felt they shouldn't suffer water scarcity in the presence of abundance of water from the rain.

This option was open to respondents who harvested rainwater.

Table 4.5 Influencing Factor for collection

| Influencing factor | Frequency | Percentage (%) |
|---|---|---|
| Extension Agents | 3 | 3 |
| Observation | 83 | 83 |
| Other Factors | 14 | 14 |

### 4.2.4 Storage of harvested water

This option was also open to respondents that collected rainwater. Eighty-five percent (85%) of the respondents store the harvested water in either Buckets or Drums or Containers. Fifteen percent (15%) channelled the water to either Overhead or Surface or Underground tanks. None of the respondents directly channelled the water to the land.

Table 4.6 Storage media of collected rainwater

| **Storage Medium** | **Frequency** | **Percentage (%)** |
|---|---|---|
| Drums/Buckets | 85 | 85 |
| Tanks | 15 | 15 |
| Direct Land Application | 0 | 0 |

### 4.2.5 Treatment of collected water

This option was also open to respondents that collected rainwater. Fifty-six percent (56%) of the respondents that harvest rainwater suggested that they used it for their domestic purposes without treating. Twenty percent (20%) boiled the water to make it more suitable for their use, seventeen (17%) carried out filtration while seven (7%) used chemical to treat the water.

### 4.2.7 Major source of water for irrigation

This question was open to respondents that practiced irrigation on their farms/gardens

Most respondents did not reply to this option as they did not really participate in farming. Those who responded had small gardens where they practised subsistent agriculture (growing mainly vegetables).

About Sixty-one percent (61.2%) depend on Pipe-Borne water; Twenty-one percent (21.2%) depended on streams while Eighteen percent (18%) depended on wells.

Table 4.9 Major Source of water for Irrigation

| **Major Source of Water (Irrigation)** | **Frequency** | **Percentage (%)** |
|---|---|---|
| Pipe-Borne water | 52 | 61.2 |
| Wells | 18 | 21.2 |
| Streams | 15 | 17.6 |

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## CHAPTER FIVE

# 5. CONCLUSION AND RECOMMENDATIONS

### 5.1 Conclusion

The study was carried out to assess the adoption of RWH technologies and their contribution to livelihoods (domestic) in Kubwa. Data was collected mainly through questionnaire survey and subjected to statistical analysis and explanations.

It was discovered in the course of the research that the level of awareness in Kubwa was a hundred percent (100%) but techniques of collection and storage, was poor as residents run out stored water few days after rainfall.

Fifty percent (50%) of the residents attributed their lack of interest in the collection of rainwater to:

- Height of the building in which they reside
- Ownership of tanks in which they store water for short spell scarcity
- Ownership of Wells and bore-holes to supplement the public water supply
- Concerns regarding the potability of Rainwater

Eighty-six percent (86%) of respondents who harvested rainwater restricted its use to non-potable domestic use. Eleven percent (11%) harvested rainwater for their commercial ventures while Three percent (3%) harvested rainwater for small-scale irrigation.

Eighty-three percent (83%) of the respondents that collect rainwater attributed their collection to unreliability/inaccessibility of the Public water supply to satisfy their domestic needs. About Six percent (6%) attributed their collection to diminishing returns from the wells.

About Eleven percent (11%) of the respondents specified that conditions they simply practised it as a water conservation technique.

Eighty-five percent of respondents harvested the water in drums; buckets/containers while a total of forty-four percent (44%) carried out some form of treatment on the water to make it suitable for their use.

## 5.2 Recommendations

The above enumerated problems as regards water scarcity could be resolved or reduced in short or solved long term if the following recommendations are carried out:

i. Rainwater harvesting structures for groundwater recharge and for domestic and agricultural use is a feasible structural adaptation option as it would enhance an all year round provision of water. New policies to promote rainwater harvesting need to be developed.

ii. Awareness programs and enlightenment campaigns on the benefits of RWH as a water conservation practice, water provision method, ecological system conservation etc as residents experience perennial flooding.

iii. Scientific research and evaluation of rainwater harvesting applications through research and development may be carried out for encouraging affordable and economic solutions to enhance the effectiveness of systems and adaptation to the impacts of climate change.

iv. Encourage builders to incorporate rainwater harvesting systems into their design and construction of new residential, commercial and industrial facilities in the community. Harvested rainwater at these locations if not treated may be used for non-potable uses.

- Concerns regarding the potability of Rainwater

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v. Participatory water harvesting systems for domestic and agricultural use can be integrated into water resources development and management plans at local, regional and national levels.

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vi. Awareness and knowledge of ecosystem services must be increased amongst practitioners and policy makers alike, to realise the potentials of rainwater harvesting and ecosystem benefits for human wellbeing.

In tune with this project, it has thrown light into areas of rainwater harvesting techniques where future research work on rainwater harvesting could be profitably resourced for.

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