Nigerian Research Journal of Engineering and Environmental Sciences 3(1) 2018 pp. 287-304

Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

Review Article

RAINWATER HARVESTING FOR WATER SUPPLY AND INTEGRATED DEVELOPMENT IN RURAL AND SEMI-URBAN AREAS

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ARTICLE INFORMATION

Article history:
Received 21 May, 2018
Revised 26 May, 2018
Accepted 30 May, 2018
Available online 30 June, 2018

Keywords:
Rainwater harvesting
Roofing materials
Rural and semi-urban
Storage tank
Water supply

ABSTRACT

The major challenges engineers are facing today is how to find ways and means of designing systems which use local technology for sustainable development and at the same time satisfies basic human needs. Despite new development paths in terms of water supply and sanitation being put in place that avoid the error(s) of the past, yet it is difficult to imagine how sustainable development in the rural areas will be if renewable fresh water in form of ground and surface waters are in short supply. This suggests that rainwater harvesting should be given priority attention and revived as a sustainable alternative for water supply as well as for integrated development. Rainwater quality is generally good and frequently meet WHO guidelines, which is perceived to be largely dependent on the type of roofing materials used and frequency of cleaning of the surface. Different possible users' regimes which can suit different parts of the country were presented in this work, including the major structural components of rainwater system, planning and design approach of rainwater system, management, the potential effect and impact of the system. The various types of storage tanks and explanatory insight on storage tank construction, the materials needed and the cost implication for long and short term planning were also presented. The major external factor that could limit the use of rainwater harvesting on a large scale in rural and semi-urban areas in Nigeria is the use of traditional method of roofing (thatch). Therefore, for the system to be successful, there must be a shift from traditional method of roofing to the impervious materials-corrugated metal sheets, and where possible tiles.

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1. INTRODUCTION

Water is life, and it is essential for food production and economic development of any country and the world at large (Eckardt *et al.,* 2009; Pati, 2015; Rasul, 2016). Water being one of our precious natural resources, is something that most of us take for granted (Wade, 2010). With the present awareness of its importance to our survival and its limited supply, considerable attention must be given to how we source it, use it more efficiently because no technology can significantly expand this basic resource (Floros *et al.,* 2010; Dubois, 2011). Over the long time, the water humanity can count on for use, year after year, is the same as the plant renewable supply, and this is the water that falls from the sky, seeps in to ground or collects in rivers and lakes, and flow back to the sea, from which it was first drawn up by the sun (Engelman and LeRoy, 1993).

Falling rain can provide some of the clearest naturally occurring water that is available anywhere, and the collection simply involves the collection of water from surface on which rain falls, and subsequently storing this water for a later use (Asenso *et al.,* 2010). A common practice found in most areas in the world and in particular Nigeria is the collection of water from roofs of buildings and stored in small or medium rainwater storage containers (Lade and Oloke, 2013; Rahman *et al.,* 2014; Liuzzo *et al.,* 2016). In some part of the world, water is collected in dams from rain falling on the ground and providing runoff (Pimentel *et al.,* 2004). Whichever method used, the primary objective is that the water collected can be considered to be precious and should be efficiently utilized (Bhutani, 2014).

In Nigeria, rainwater harvesting has not been given considerable attention as a possible source of water supply for sustainable development. The practice is only limited to domestic use during period of rainy seasons when there is a short or intermittent supply from the town or city water supply system (Ishaku *et al.,* 2011; Akpabio, 2012; Liuzzo *et al.,* 2016). The practice is not done to a large extent to accommodate agricultural use as is being done elsewhere in the world, especially in Brazil and a dry continent like Australia. Within the last two decades, interest in rainwater harvesting across the globe has grown. Its utilization is now an option along with more "traditional" water supply technologies, particularly in rural areas of some continent e.g. Asia and the America. Rainwater harvesting is of particular importance and relevance for arid and semi-arid regions, remote and scattered human settlement of our country. Jo, (2003) reported that the increased interest in rainwater harvesting has been facilitated by a number of external factors such as:

1. The shift towards more community-based approaches and technology which emphasize participation, ownership and sustainability.
2. The increased use of small scale water supply for productive and economic purposes (livelihoods approaches)
3. The decrease in the quality and quantity of ground and surface waters
4. The failure of many piped water supply system due to poor operation and maintenance
5. The flexibility and adaptability of rainwater harvesting technology
6. The replacement of traditional roofing (thatch) with impervious materials (e.g. tiles, and corrugated iron)
7. The increased availability of low cost tanks (e.g. made from ferro-cement or plastics).

The sixth factor is a major external factor limiting the use of rainwater harvesting method on large scale in rural and semi-urban areas in Nigeria. Until the rural populace is financially equipped to replace traditional roofing materials or resort to the use of modern roofing materials, the rainwater harvesting for sustainable development may continue to remain an illusion in this country.

This paper gives an overview of the importance and benefits in rain water harvesting, component of rain water system, planning and management, design approach and the potential effect and impact of the system and finally to establish the need for rainwater harvesting.

1.1. The Problem and the Need

Life is tied to water as it is tied to air and food. In the past decades, access to secure water has been essential to social and economic development and the stability of cultures and civilization (Fogden and Wood, 2009; Floros *et al.,* 2010; Misra, 2014). In Nigeria presently, new development paths in terms of water supply and sanitation are been put in place that avoid the errors of the past, yet it difficulty to imaging how sustainable development in the rural area will be if renewable fresh water is in short supply. People need sources of clean water close to home. Where ground water and surface water are in short supply, rainwater may be the only suitable alternative or supplement. In some parts of the world notable in western Europe, the Americans and Australia, rainwater has continued to be an important water for isolated home steads and farms (Jo, 2003; Chidamba, 2015). Collection and storage for agricultural use has equally been widely practiced for thousands of years as mentioned in ''Dying wisdom. Rise, fall and potential India's traditional harvesting system gives a good industrial overview of such practices in India'' (Agarwal and Narain, 1997).

1.2. Importance of Technology

The importance of rainwater harvesting can be categorized into the following five (5) major dimensions:

1. If an individual is not connected to a town water supply, then rainwater collection is important in such situation
2. If an individual is from a city then it is possible to replace all or at least a substantial portion of fresh water requirement by the capture and storage of rainwater from rooftops
3. In arid and semi-arid regions, where precipitation is low or infrequent during the dry season, notably most dry parts of northern Nigeria, it is necessary to store the maximum amount of rainwater during the wet season for use at a later time, especially for domestic purpose.
4. Farm water supplies (built to provide drinking water for livestock and wild life)
5. Irrigation purposes.

1.3. Benefits in Rainwater Harvesting

1. Rainwater harvesting, if adequately adopted can largely increase self-sufficiency in water supply for a vast majority of people living in rural and semi-urban areas of the country
2. It can significantly reduce reliance on other water storage facilities (dam). This imply less stress on this water stored and reduce need to expand these storage facilities or build new ones
3. Significant reduction in water bills from a water supply system can be achieved when an individual collects and uses rainwater
4. The menace cause by the flow of storm water can also be reduced and this minimized the likelihood of overloading our storm drainage system in our environment
5. Rainwater harvesting if adequately adopted can be a method of decreasing amount of treatment necessary for combined sewer system

2. RAINWATER HARVESTING REVIVAL

In Nigeria, rainwater harvesting has not been given considerable attention as a possible source of water supply for sustainable development. The practice is only limited to domestic use during period of rainy seasons, when there is a short or intermittent supply from the town or city water supply system.

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The Federal Ministry of Environment is developing roof rainwater harvesting infrastructure in three states of the federation. The targeted states are Adamawa, Gombe and Bauchi states. The process was simply to collect rainwater when it fell and would be stored and utilized at a later point and this would lessen the burden of soil erosion, in other words, allowing the land to thrive once again. The rainwater can be purified into drinking water used for daily applications and even utilized in large scale industries. Rainwater harvesting is a process or technique of collecting, filtering, storing and using for irrigation and for various purposes. In areas where there is excess rainfall, the surplus rainwater can be used to recharge ground water through artificial recharge techniques. In addition, rainwater can also be stored in cisterns for use during times when water supplies are at an all-time low.

Rainwater harvesting (RWH) is mostly practiced in the southern part of the country, as rainfall is regular for eight months of the year, with a mean annual fall of 1200-2250 mm. The rainy season is from May/June to September/October, depending on the rainfall pattern each year (Nthuni *et al.,* 2014; Adugna *et al.,* 2018). The other months are generally dry, with cool Harmattan winds between November-March. Rainwater harvesting is practiced at individual, household, commercial and occasionally at local or state government level, to augment dwindling water supplies to urban centres (Omolara and David, 2015).

2.1. Cultural Acceptability

Rainfall harvesting has been practiced for many years by different communities in Nigeria and the method has been accepted as freshwater argumentation system over the decades. But despite this acceptance, it has not been widely adopted as a source of water supply on large scale (Biswas and Mandal, 2014; Lade and Oloke, 2015). However, rainwater harvested from properly maintained rooftop catchment systems and stored in good containers and good covers is generally suitable for drinking and frequently meets WHO guidelines for drinking water (White *et al.,* 2007; Domènech *et al.,* 2012). The bacteriological quality of rainwater collected from ground catchments is poor (Lye, 2009; Chubaka *et al.,* 2018).

2.2. Rainwater Sources and Types of use

People collect and store rainwater throughout the world. Rainwater can be collected in a variety of different forms and for different purposes. Rainwater harvesting can be categorized according to the type of catchment surface used. This also indicate the scale of activity (see Figure 1).

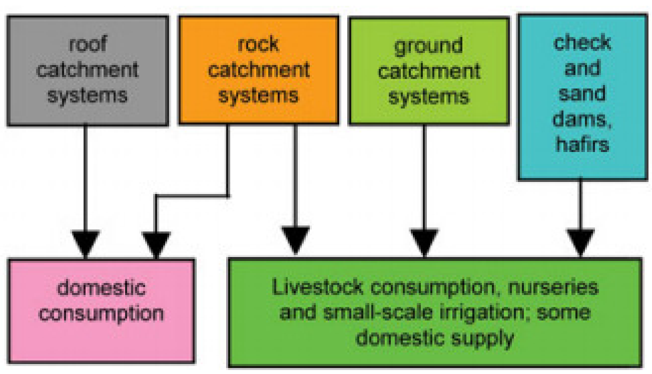

Figure 1. Small-scale rainwater harvesting systems and uses (adapted from Gould and Nissen Petersen, 1999).

2.3. Users Regimes/Patterns

Rainwater harvesting is used in many different ways depending on the need and conditions or situations. In some situations, it is used merely to capture enough water during a storm to save a trip or two to the main water source (walking distance) and in such cases, only small storage capacity is required, maybe just a low small pots or jars to store enough water that can sustained the household for a day or a hold a day (Jean Charles, 2007). Between these two extremes exists a sequence of different user patterns, and variables that determines these patterns of usage for rainwater harvesting.

2.3.1. Rainfall quantity (mm/year)

This refers to the total amount of water available to the consumer and is a product of the total available rainfall and the collection surface area. Usually there is a loss coefficient included to allow for evaporation and other losses. Means annual rainfall data will indicate how much rain falls in an average year. Table 1 gives the mean annual rainfall data of the country.

Table 1: Annual Average Rainfall before 1979 and in the 1980 decreasing rates (%). (Source: National Water Resources Master Plan by JICA, 1995). (Units: mm per year)

Region	Station	Average Rainfall before 1979	Average Rainfall in the 1980s	Decreasing rates (%)
NW	Sokoto	706	535	24
NE	Kano	839	684	18
NE	Maiduguri	672	455	32
CW	Kaduna	1 290	1155	10
CE	Jos	1378	1273	8
SW	Ikeja	1625	1372	16
SE	Enugu	1795	1593	11
SE	Calabar	2823	2765	9

2.3.2. Rainfall pattern

Climate condition vary widely throughout the world. The type of rainfall pattern, as well as the total rainfall which prevails will often determine the feasibility of rainwater harvesting system (RWHS) (Mzezewa *et al.,* 2010; Biswas and Mandal, 2014). A climate where rain falls regularly throughout the year (Southern Nigeria) will mean that the storage requirement is low and hence the system cost will be correspondingly low and vice versa. More detailed rainfall data is required to ascertain the rainfall pattern. The more detailed the data available, the more accurately the system parameters can be defined (Koutsouris *et al.,* 2017).

The rainfall pattern in Nigeria shows great variations, unequal seasonal distribution and more unequal geographical distribution. The southern part of the country receives rainfall in excess of 1500 mm. Annual rainfall of 1000 mm - 1500 mm is experienced in the middle belt regions while the arid and semi-arid region of the north receives less than 1000 mm of rain annually. The number of annual raining days influence the need and design for rainwater harvesting. The fewer, the annual rainy days, or longer the dry period, as it is experienced in the northern part of the country, the more the need for rainwater collection in this region and because the dry period is too long, sometimes over stretching more than six months, big storage tanks would be needed to store rainwater (Olaniran, 2002; Ikhile and Aifesehi, 2011; Guhathakurta and Saji, 2013; Salihu and Guariso, 2017).

2.4. Effectiveness of the System

The notable factors affecting the possibility of adopting rainwater harvesting in a particular area is highly dependent upon the amount and intensity of rainfall. Other important factors are catchment area and type of surface (Ibrahim, 2012; Biswas and Mandal, 2014; Maina and Raude, 2016; Prasad *et al.,* 2017). These can be adjusted to suit individual needs. It is worthy to note that rainfall is usually unevenly distributed throughout the year, thus rainwater collection methods can serve only as supplementary source of fresh water for the household (Boers and Ben-Asher, 1982). The adaptability and viability of rainwater harvesting systems is also a function of cultural acceptability, the quality and quantity of water available from other sources, household size and per capita water requirement and capital available (Christian Amos *et al.,* 2016; Khoury-Nolde, 2016; Fisher-Jeffes *et al.,* 2017).

Records of serious illness associated or linked to rainwater supplies are few, indicating that rainwater harvesting technologies are effective sources of water supply for various purposes. Contrary to popular beliefs, rather than becoming stale with extended storage, rainwater quality often improves as bacteria and pathogens gradually die off (Gould and McPherson, 1987; Gould, 1999; Mosley, 2005; WHO, 2008). In some parts of the world (semi-arid and arid regions) rainwater harvesting is used for irrigation purposes, it also promotes improved management practices in the cultivation of corn, cotton, sorghum and many other crops. It also provides additional water supply for livestock consumption (Recha *et al.,* 2012; Macauley and Ramadjita, 2015).

2.5. Suitability and Development Cost

This technology coupled with municipal water supply is suited to both urban and rural areas. The construction of local storage tank using available cement materials or provision of conveyance system (gutters) does not require very highly skilled labour. The capital cost of rainwater harvesting system is very much dependent on the type of catchment, conveyance and storage tanks materials used. Compared to deep and shallow tube wells, rainwater collection and system are more cost effective, but can be a little higher if the initial investment include the cost of roofing materials. The most expensive part of a rainwater harvesting system is usually the storage tank or reservoir itself, which depends on cost of materials, storage capacity and construction. The reported operation and maintenance costs are negligible (Gretchen, 2003; Thomas and Martinson, 2007; Barnes, 2009).

2.6. Maintenance

Rainwater harvesting technology generally require very little maintenance and is limited to annual cleans of the tank and regular inspection of the conveyance systems. Maintenance is done primarily to remove dirt, leaves and other accumulated materials. If rainwater is to be used for drinking water, the inside of the finished storage tanks should be scrubbed with a 10 percent bleached solution and rinsed thoroughly before the systems is used (Gretchen, 2003). It will also need to be drained and emptied of accumulated sediments every few years.

2.7. Advantages

Rainwater harvesting are simple to install and operate, the local people can be easily trained to implement such technologies, the construction materials are locally available, and the running cost are almost negligible because of reduced operation and maintenance problem. Rainwater harvesting has few environmental impacts compared to other water supply projects technologies and water collection and storage capacity may be increased as needed within the available catchment area (household capacity and needs).

2.8. Disadvantages

Rainwater harvesting cannot be implemented where there is limited supply and uncertainty of rainfall and also the additional initial cost incurred in implementing this technology could be a factor for some people since the effectiveness of the system/technology can be limited or be less attractive to some governmental agencies instituted with providing water supply in the country. The adoption of the technology requires mobilization of local government and NGO's resources to serve the same basic role in the development of rainwater-based schemes.

2.9. Rainwater uses

Rainwater use depends on the collecting catchments. Rainwater collected from roof catchments which is always clean are used for cooking and food preparation, drinking purposes, general home cleaning, water lawn and gardens, filling swimming and washing pools, washing cars and sprinkling and for livestock and wildlife consumption (Brown *et al.,* 2005; Che-Ani *et al.,* 2009).

2.10. Rainwater Tanks

The storage tank is a key component apart from the roof catchment systems for rainwater harvesting in the rural communities in Nigeria, and the commonly used ones are the earthen pot and small plastic containers. The storage tank is usually the most expensive part of the system, which calls for the use of earthen pot, and small plastic containers which can be produced locally and less expensive. As far as users are concerned, the rainwater tank is the focus of the catchments system. Rainwater tanks may be classified based on their use into three categories: (i) Individual household storage water tanks, (ii) Community rainwater storage tanks, and (iii) Tanks used with surface catchments.

There are many different kinds of tanks with each of these categories. Each has its own construction technology and techniques, materials costs, and labour requirements. This technical note contains over views of various types of tanks to enable users to enter into decision on the choice and design of rain water tank to meet their individual needs.

2.10.1. Choice of tank

There are many different water storage choices and manufacturers have developed ground-breaking solutions in recent years, though many factors need to be considered when making decision on the type of tank to be installed and include: How much water is needed and that can be collected and stored and the expected or required life span of the tank? What material and the least cost can be obtained locally and feasible? Finally, the amount and frequency of the rainfall is very important.

2.10.2 Different type of tanks

There are a number of different types of rainwater harvesting system that are used all over the world, the cost varying with the complication and size of the technology being installed. They all have one thing in common which is to utilize our natural rainfall to supplement the mains supply we all take for granted. The major benefit of rainwater harvesting is that it can be done on small and much larger, even industrial scales. Some of the available tanks in Nigeria includes; plastic tanks, traditional baskets, cement mortar jar, ferrocement tanks, manufactured in or corrugated metal sheet tanks, concrete tanks and masonry and brick tanks.

3. GENERAL DESCRIPTION

The term "rainwater harvesting is usually taken to mean "the immediate collection of rainwater running off surface upon which it has fallen directly (Pacey and Adrian, 1986). This definition excludes runoff from land watersheds into streams, rivers, lakes etc. Thus, the capturing and collection of rainwater from the roofs of buildings can easily take place within our cities, towns and rural areas. All that is necessary to capture this water is to channel the flow of rainwater from roof gutters or rooftops to a rainwater storage tank or reservoirs. By so doing water can be collected and used for domestic and agricultural purposes. In most part of Africa, and Nigeria in particular the use of simple techniques such as jars and pots are used for collection of rainwater. The techniques arise from practice employed by ancient civilization and still serve as a major source of drinking water supply in rural areas.

3.1. Technical Description and Materials for Rooftop Harvesting

Generally, rainwater harvesting systems have three (3) components viz: a collection area (the catchment surface roof and other surfaces), a conveyance system (the delivery system to transport the water from the roof to the storage reservoir), and a storage area (the reservoir to store the rainwater until it is used).

3.1.1 Materials for rooftop harvesting

The efficiency of rainwater collection depends on the materials used, the construction, maintenance and the total rainfall (Jo, 2003). The following materials have been generally recognized and these includes; the galvanized corrugated iron or plastic sheet or tiles, thatches roofs made from palm leaves (coconuts and anahow palms with thatching are best). Other thatching materials and mud discolor and contaminate the rainwater (Jo, 2003).

Unpainted and uncoated surface area are best, the asbestos- cement roofing does not pose health risks, as no evidence is found in many research (Meera and Ahammed, 2006; Abbasi and Abbasi, 2011). However, the airborne asbestos fibers from cutting, etc. do pose a serious health risk (cancer) if inhaled (Stayner *et al.,* 1996; Berman and Crump, 2008). The timber or bamboo pose no health risk and are also used for gutters and drainpipes. For use, these materials need regular replacement than preservation. Timber parts treated with pesticides to prevent rusting should never come into contact with drinking water (Kaminski *et al.,* 2016).

3.2. Design Approach for Rainwater Harvesting Systems

The design of an individual rainwater harvesting systems as reported by Gretchen (2003) depends on the following factors; the planned water use, either for domestic use or agricultural (irrigation purposes), the household population or layout of the yard or farmstead, and the reliability of water supply that is needed. Different approaches are taken in different parts of the world. However, a case study of Montana home owners (Gretchen, 2003) suggested the following steps; estimate in whether rainwater could satisfy the identified need, decide in the needed reliability of the supply and size are to locate the catchments area, the size and design of the storage reservoir or tank, and then select, locate and size the appurtenances. Jo (2003) reported that tank size varies depending on rainfall pattern and user group; household may need a tank of from 1m^3 to more than 40 m^3, while schools and hospital may need tanks, up to 100 m^3. The report suggested that, when there are long day season, roof collection area and tank size will be large but rationing (good management) and use of alternative sources significantly reduces the required surface area and tank volume. In general, required roof area and tank volume increase as total rainfall decreases, or where rainfall pattern becomes erratic.

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3.3. Designing Rainwater System

In designing of a rain water harvesting system, rainfall data is required at least for 10 years period. The more reliable and specific the data is for the location the better the design will be. Table 3 shows the average rainfall in the eight hydrological stations of the country. Calabar station (South East region) has the highest annual average rainfall of 2765 mm, while Maiduguri station (North East region) has the least average annual rainfall of 455 mm in the 1980's (JICA, 1995).

Water consumption and demand for domestic purposes is also expected to vary among these regions due to socio-economic condition and different uses of domestic water. In south east region of the country where most areas are guinea worm affected areas, rainfall harvesting will supply a clean water free of infestation. In northern dry area where water availability is deficient rainfall harvesting is an advantage. People may use as little as a few litres per day. A 20 lpd (gallons or capita per day) is the commonly accepted minimum (WHO, 2004; Sawka *et al.,* 2005; De Buck *et al.,* 2015). In the design of rainwater harvesting systems an estimate of the amount of water required for economic and productive uses should be added (Jo, 2003). This is done when roof rainwater harvesting is only to provide sufficient water for a small vegetable plot. This practice is not common in this country and is strongly advocated. Jo, (2003) suggested that water demand can be computed from the following expression: Water Demand = 20 x n x 365 litres / year, with n = number of people in the household.

3.3.1. Water harvesting potential of a site

Rainwater supply depends on the annual rainfall, the roof surface and the runoff coefficient. Table 2 gives types of catchments material and their runoff coefficient.

Table 2: Types of catchments materials and runoff coefficients (Adapted from Pacey and Adrain, 1989)

Type of catchments	Materials	Runoff coefficients
Roof catchments	Tiles	0.8-0.90
	Corrugated metal Sheets	0.7-0.90
Grand surface coverings	Concrete	0.6-0.80
	Brick pavement	0.5-0.60
Untreated ground catchments	Soils on slope less than 10 percent	0.0-0.30
	Rocky natural catchments	0.2-0.50
	Green area	0.05-0.1

Based on the above factors, the water harvesting potential of an area could be estimated using Equation 1:

$$\text{Water supply} = \text{Rainfall (mm/year)} \times \text{area of catchment (nr)} \times \text{runoff coefficient (n)} \qquad (1)$$

4. APPLICATIONS

Available data on average annual rainfall for eight (8) hydrological stations in the country has been presented in Table 1. For instance, using Table 1 and choosing Maiduguri station (NE) with average rainfall 455 mm and Kaduna station (CW) with average rainfall 1,155mm, water demand and water supply can be computed for both stations.

Assume that, there is an average of six people in a household, then water demand for Maiduguri station will be:

Water demand = 20 x n x 365 litres/year, n = number of people in the household

Water demand = 20 x 6 x 365

This gives 43,800 litres/year for a household in Maiduguri which is about 3650 litres/month. This imply that for a given dry period of six months, the required minimum storage capacity will be 21,900 litres (5475 gallons). This is however a rough estimate 1 gall = 4litres

For a metal roof sheet of 100 m^2 and a runoff coefficient of 0.8.

Water supply = 455 x 100 x 0.8

= 36,400 litres/years (9100 gallons/year).

To compute that of Kaduna station, water demand for a household will thus be:

Water demand = 20 x 6 x 365 litres/ year

= 43,800 litres/year, similar to that of Maiduguri station

Rain water supply for Kaduna;

Water supply = Rainfall (mm) x roof area x runoff coefficient

From Table 1, average annual rainfall for Kaduna is 1,155mm

Supply = 1,155 x 100 x 0.8 = 92,400 litres/year

5. SIMPLE ILLUSTRATION OF WATER HARVESTING POTENTIALS OF EIGHT HYDROLOGICAL STATION IN NIGERIA

Table 3 presents estimated values of water harvesting potentials for the eight hydrological stations of the country. From Table 3, it could be seen clearly that for a roof area of 100 m^2 and an average rainfall of 455 mm in Maiduguri, a person can gladly store 36,400 litres, which is above the maximum storage requirement of 21,900 litres for a six-month duration of dry months in Maiduguri. Also, in the case of Kaduna, it will be observed that for the same roof area and average rainfall of 1,155mm, a person can gladly store 92,400 litres/year which is well above the minimum storage requirement for a household of 21,900 litres for a period of six dry months.

Results also indicate that stations like Sokoto, Kano and Maiduguri where rainfall water is scarce, and cannot meet up demand per annum, large catchment roof area is required to improve collection of water to meet the demand within these regions. Conversely, regions with much rainfall such as Jos, Ikeja, Enugu and Calabar, excess water collected can be used for small garden plots. It should be noted that roof rainwater harvesting is only able to provide sufficient water for a small vegetable plot. Such rainwater collection is strongly recommended for practice in Nigeria for integrated development.

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Table 3: Estimated values for average water demand required, minimum storage runoff coefficient and water harvesting potentials of eight hydrological station in the country

Region	Station	Average rainfall (mm)	Runoff coefficient Corrugated metal sheet	Water demand per average of six people in household	Water demand for a household litres/month	Required minimum storage capacity	Water harvesting potential of each litres/gallon station (rainwater supply) litres/annum
NW	Sokoto	535	0.7-0.9	43,800	3,650	21,900	42,800
NE	Kano	684	0.7-0.9	43,800	3,650	21,900	54,720
NE	Maiduguri	455	0.7-0.9	43,800	3,650	21,900	36,400
CW	Kaduna	1,155	0.7-0.9	43,800	3,650	21,900	92,400
CE	Jos	1,273	0.7-0.9	43,800	3,650	21,900	101,848
SW	Ikeja	1,372	0.7-0.9	43,800	3,650	21,900	109,760
SE	Enugu	1,593	0.7-0.9	43,800	3,650	21,900	127,440
SE	Calabar	2,765	0.7-0.9	43,800	3,650	21,900	221,200

6. COSTS

The cost of rainwater collection systems (tanks) are minimal. The main cost of this technology is in the materials and labour required to build the storage tank. Table 4 shows a roughly estimated cost for construction of a storage tank locally in Nigeria. The assumed tank storage capacity is $25m^3$ which is considered adequate to store rainwater supply of 21,900 liter (5475 gallons) for a dry period of six months for average number of six people in a household and the system cost-estimate in most parts of the country where the water supply is of poor quality, erratic or expensive. In areas not served by a municipal water supply, or in drought prone areas, installing a rainwater catchments system may actually be the most convenient and economical option. In a situation where the economy may not permit the individual to construct tank of this capacity ($25m^3$), an alternative small storage tank capacity of $l0m^3$ presented in Table 5 might be considered as an option.

7. PLANNING

Domestic rainwater harvesting needs to be seen as only part of a system to meet the overall water requirement of a household or community. Other sources, notable public water supply will compliment demand (Amiraly *et al.,* 2004; Reitano, 2011). Any projections for future planning must take the form of a people-centered approaches, taking into account the socio-economic, cultural, institutional, and gender aspects of the people, as well as the community perception, preference and abilities. Four factors can be identified for success in domestic rainwater harvesting and these are:

1. Project start and grow slowly to allow for testing and modification of design and implementation strategy.
2. Demand for water is clearly expressed
3. Full involvement of both sexes in all project stages

4. Substantial contributions from the people in ideas, funds and labor

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Table 4: Estimated cost of construction of small tank for domestic rainwater collection (25 m^3 Capacity)

Material	Quantity	Rate (N)	Amount (N)
Cement	45 bags	2700 x 45 bags	121,500.00
Plain wire 2.5 mm diameter (RBC mesh)	Supplied per length of 12 m = 1,080 for 42 m	1080 x 42	45,360.00
Chicken mesh 1mm diameter (Chicken net)	A roll almost about 6500 N 406.25 + tiering wire – N43.75 = 406,25 + 43.75 = N450.00	450.00 x 40	18,000.00
Water 20 mm bore (UPVC, Bar. dia = 1mm)	1m	350.00	350.00
Water tap (Plastic)	1No	1,000.00	1,000.00
Over flow pipe (Plastic)	1No	750.00	750.00
38 gauge galvanize iron (10 sheet = 12 m^2 12 x 2.5 = 30 m^2)	30 m^2	595.00 x 30	17,850.00
Sand (3.8m^3 lorry capacity)	3 trips	8,000.00 x 3	24,000.00
Gravel (3.81 lorry capacity)	3 trips	25,000.00 x 3	75,000.00
		Sub-total	303,810.00
Labour (20 %)			60,762.00
		Sub-total	364,572.00
Contingency (5 %)			18,228.60
		Sub-total	382,800.60
Vat (5 %)			19,140.03
Grand total			401,940.63

8. MANAGEMENT

Management by individual households is not successful, this is because the user (often a woman) operates and control the system, is responsible for its maintenance, manages the use of water (minimum misuse), and appropriates the convenience of water next to her home (Mack and Choffnes, 2009; Omisca, 2011).

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Table 5: Estimated Cost of Small tank for Domestic Rainwater Collection (10 m^3 Capacity)

Material	Quantity	Rate (N)	Amount (N)
Cement	24 bags	2,700 x 24 bags	64,800.00
Plain Wire 2.5 mm diameter (RBC mesh)	Supplied per length of 12 m = 1,080 = 200/12 = 16,667 m	1,080 x 16 x 16.667	18,000.00
Chicken mesh 1m dire (Chicken net)	A roll is almost 6,500 = 10000/16 = 625 + tieing wire = 43.75 = 625 + 43.75 = 668.75	668.75 x 16	10,700.00
Water pipe 20 mm bore (UPVC, Bar. dia = 1mm)	1m	350.00	350.00
Water tap (Plastic)	1No	1,000.00	1,000.00
Overflow pipe (Plastic)	1 No	750.00	750.00
38 gauge galvanized iron roof sheet + angle iron (10 sheets)	12 m^2	595.00 x 12	7,140.00
Sand (3.81 m^3 lorry capacity)	1 trip	10,000.00	10,000.00
Gravel (3.81 m^3 lorry capacity)	1 trip	25,000.00	25,000.00
		Sub-total	136,540.00
Labour (20 %)			27,308.00
		Sub-total	163,848.00
Contingency (5 %)			8,192.40
		Sub-total	172,040.40
Vat (5 %)		Sub-total	8,602.02
Grand total			180,642.42

8.1. Potential Effects and Impact

With a good livelihood strategy, rainwater is both a key to domestic and productive resource the effect of rainwater harvesting is therefore multiple in terms of health, poverty reduction, education and equity (Amha *et al.,* 2008; Omisca, 2011; Ibrahim, 2012). These includes:

1. Reduction of burdens of the poor as less time is spent in collecting water, particularly for women and children
2. Reduction in water related diseases as quality is usually better than water sourced traditionally. The impact is less sick days savings on medical expenses and time for more economic activities
3. Improve health status as excess rainwater is used for vegetable and crop growing which provides improved diet.

4. Improved economic and health status from income from vegetable and other crops, and other economic activities using water.
5. Less back problem and growth reduction, particularly among children and women as transportation of heavy loads over long distance is reduced.
6. More time for education and personnel development, particularly for young girls as time is now used for school attendance or home work.

9. CONCLUSION

Rain water harvesting appears to be one appears of the most promising alternatives for supplying fresh water in the face of increasing water scarcity and escalating demand. The pressure on rural water supplies, greater environmental impact associated with new projects and increased opposition from NGOs to the development of new surface water source as well as the deteriorating water quality in the surface reservoir already constructed, constraint the ability of communities to meet the demand for free water from traditional sources and present an opportunity for argumentation of water supply lies using this technology. The rainwater harvesting technologies are simple to install and operate. Local people can be easily trained to implement such technologies and construction material are also readily available. Rainwater harvesting is convenient in the sense that it provides water at the point of consumption and family member have full control of their own system, which greatly reduce operation and maintenance problem. The capital cost of rainwater harvesting system is highly dependent on the types of catchment, conveyance and storage tank material used, and also if the initial investment does not include the cost of roofing materials. Running cost also are almost negligible. Water collected from catchment is usually of acceptable quality for domestic purpose for the reason that the quality of water collected from roof catchment meets the World Health Organization (WHO) Standard Guideline for drinking water. But for irrigation purposes ground catchment is best adopted. Maintenance is generally limited to annual cleaning of tank and regular inspection of the gutter and down pipes-maintenance typically consist of the removal of dirt, leaves and other accumulated materials. Such cleaning should take place annually before the start of major rainfall season.

10. RECOMMENDATIONS

The experience and results of this research work lend credence to the following recommendations:

1. The only water source available to both the rich and poor of the same geographical location to remain self-sufficient is rainwater.
2. A viable solution to the acute problem in water supply in Nigeria is rainwater harvesting and specifically roof catchments as most areas have good seasonal rainfall.
3. The only and cheapest means of providing such water is by providing storage cistern (tank) and catchment area mostly roof in every family and compound as the residents may desire.
4. Investment to build storage tank in roof catchments has multiple cash profit, which increases arithmetically as the life span of the structure increases.
5. Practice of roof catchment system is home based, importation free, economically viable and thus foreign reserve bonus to any country, compare to other method of water supply because the raw materials needed are available in all localities. The manpower requirements are also available and therefore pumping of water would no more be a problem.
6. The occurrence of rainfall is a natural phenomenon, which does not respect any political boundary, but rather respond to the integrity of nature and thus free political treaty and carefree attitude predominant in conventional water supplies.

7. More efforts should be geared towards the replacement of the traditional roofing (thatch) with impervious materials (e.g. tiles and corrugated iron), and proper maintenance should be carried out where necessary.
8. Encouraging rainwater harvesting and reuse requires enabling the practice through codes and regulations and providing incentives. State or municipal codes need to address public health concerns by specifying water quality and cross-contamination requirements.

The eight recommendations listed above are the major external factors liming the use of rainwater harvesting method on large scale in rural and semi urban area in Nigeria, until the rural populace is financial equipped to replace traditional roofing materials, the rainwater harvesting for sustainable development may continue to remain an illusion in the country. The shift toward more community-based approach technology which emphasis participation, ownership and sustainability of rainwater harvesting for productive and economic purposes should be rigorously enhanced and supported by the government at all levels (Federal, State, Local and Communities).

11. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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