An Alternative Source of Water Supply: Design and Construction of Rainwater Harvesting System for Domestic Use in Ovia-North East Local Government Area, Benin City, Edo State, Nigeria

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Abstract
Demand for freshwater is on the increase due mainly to population growth and urbanisation. Many of the water systems that keep ecosystems thriving and feed a growing human population have become stressed. Rivers, lakes and aquifers are drying up or becoming too polluted to use. Hence, there is need for alternative water supply sources. With this in mind, there has been a growing attention on the potentials of rainwater harvesting as an alternative source of water supply. In this study, rainwater harvesting (RWH) system was designed for a 5-membered household in Ovia-North East LGA of Benin City, Nigeria. However, a prototype of the RWH system (mini system) was constructed to ascertain its suitability. It consist of a corrugated metal (zinc) sheet catchment of $6m^2$, a collection system made of PVC pipes and a filter with granular activated carbon and fine sand and two locally available plastic storage drums having capacity of 100L each. Rainwater samples were collected from the storage drums and analysed for their suitability in domestic purposes. These samples were analysed for thirteen parameters, namely; pH, Electrical Conductivity (EC), Temperature, Turbidity, Total Dissolved Solids (TDS), Chloride (Cl), Ammonium Nitrogen (NH_4N), Nitrite (NO_2^-), Nitrate (NO_3^-), Iron (Fe), Zinc (Zn), Copper (Cu) and Coliforms Count (Col.) using standard methods. Results revealed that with a roof area of $40m^2$, $75m^3$ reservoirs or tanks capacity will be required for dry period. It was observed that all parameters analysed were within acceptable limits for drinking water quality except for coliform bacteria. Although minimum level of coliform bacteria was observed, however pure water should be free from all kinds of coliforms, thus it is recommended that the addition of a disinfectant to the harvested rainwater is required to further improve it quality for domestic use. Also proper maintenance of the catchment area and storage containers could eliminate the presence of coliform bacteria and make rainwater safe for domestic purposes. This study has revealed that the harvested rainwater is of good quality and that the amount of rainwater to be stored with a $75m^3$ reservoirs or tanks will be more than enough for a 5-membered household to meet its domestic use throughout the whole dry periods of the year. Hence, RWH can serve as an alternative and viable source of water supply.
Keywords: Catchment Area, Collection System, Runoff coefficient, Rainwater Harvesting, Rainfall, Water Demand, Water Supply.
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1. Introduction

Although, about 70% of the Earth's surface is covered with water (Shittu et al., 2015), but only about 2.5% is freshwater, with the largest portion of it lying underground (Okello et al., 2015). Demand for freshwater is on the increase due to population dynamics, especially growth and migration and this is placing unsupportable stress on freshwater supplies in many areas of the world. Water poses a serious limit to growth on human numbers and appetites (Mazur, 2009). The planet's supply of freshwater is fixed, and there is no substitute for its life-giving qualities. Still, a general water crisis is not inevitable, water resources are indisputably declining at an alarming rate all around the world (Ding et al., 2014). Hence water has to be treated as a scare resource, with a far stronger focus on managing water resources.

Water scarcity can mean scarcity in availability due to physical shortage, or scarcity in access due to the failure of institutions to ensure a regular supply or due to a lack of adequate infrastructure (UN-Water, 2021). Water scarcity already affects every continent, it is a significant and growing problem. Water scarcity affects more than 40% of the global population and is projected to increase more than this percentage. Over 1.7 billion people are currently living in river basins where water use exceeds recharge (UN-Environment, 2021). Water scarcity will continue to exacerbate as a rising world population place heavy pressure on water resources, thus the reduction of water scarcity has become a goal of many countries and governments. About 2.3 billion people live in water-stressed countries, of which 733 million live in high and critically water stressed countries and by 2025 about two out of three of the world's people will live under those conditions (UN-Water, 2021). Globally, it was reported that about 785 million people still lack access to clean water (WHO, 2017) and currently one in three people do not have access to safe drinking water (WHO and UNICEF, 2019). These people are exposed to diseases such as cholera, typhoid fever and other water-borne illness. Women and children are the most affected population when it comes to issues of water crisis. It has been estimated that about 829,000 people (of which 297,000 are children under 5 years) die every year from diarrhoea due to unsafe drinking water, sanitation and hand hygiene (WHO, 2017). Women and girls bear the burden of carrying water for their families for an estimated 200 million hours each day (World Vision, 2021). Also, without clean, easily accessible water, families and communities are locked in poverty for generations, children dropped out of schools and parents struggle to make a living. Therefore, access to clean water is a stepping-stone to development, thus efficient and effective management of our water resources is necessary especially in developing countries such as Nigeria that have been identified as water poor country (Mazur, 2009).

In Nigeria, sustainable and equitable access to safe drinking water remains a challenge. Over 86% of Nigerians lack access to a safe managed drinking water sources and this problem is compounded by poor drinking water quality and lack of equity in access. Although, 73% of the country's population have access to water source, only nine litres of water on the average is available to a Nigerian daily (UNICEF Nigeria, 2021). Recognising the growing challenge of water scarcity, the United Nations Sustainable Development Goals (UNSDGs) resolve to achieve universal and equitable access to safe and affordable water for all by the year 2030 (UNSDP, 2015). At the aforementioned current rate in Nigeria, the country will miss this sustainable development goal (SDG) targets on people's access to water, unless there is a strong commitment and appropriate action taken by all stakeholders. According to UNICEF Nigeria (2021), the world's water crisis is not coming, it is here and children are its biggest victims. In Nigerian communities, when well dry up, children are the ones missing out of school to fetch water and when water is not available children cannot wash their hands to fight off diseases. Therefore, we have to act now both to address the water crisis in Nigeria to prevent it from getting worse and if we want to meet the SDGs. There is still much work to be done in the country to ensure that all Nigerians have access to adequate and quality water and hygiene services. Water security for every Nigeria (including the Nigerian child) can be achieved through innovation, investment and collaboration, and by ensuring services are sustainable and well-managed.

Access to safe water can protect and save lives, it has the power to turn time spent into time saved when it's close and not hours away (WHO and UNICEF, 2017). Also, it can turn problems into potentials: unlocking education, economic prosperity and improved health (WHO and UNICEF, 2017; World Economic Forum, 2020). Many of the water systems that keep ecosystems thriving and feed a growing human population have become stressed. Rivers, lakes and aquifers are drying up or becoming too polluted to use (Olusegun, 2012; Shittu et al., 2015). Hence, there is need for alternative water supply sources. With this in mind, it is evident that there are considerable scopes for the collection of rainwater when it falls as the major sources of drinking water (Groundwater and surface water) account for only 40% of total precipitation (WaterAid, 2013; Biswas and Mandal, 2014). The urgency of mitigating water-scarcity related problems has focused the attention of researchers on the potentials of rainwater harvesting as an alternative source of water supply.

Rainwater harvesting (RWH) is a simple technique of collecting the run-off from a structure or other impervious surface in order to store it for later use such as domestic, agricultural, industrial and environmental uses (Tobin et al., 2013). Traditionally, this involves harvesting the rain from a roof. The rain will collect in gutters that channel the water into downspouts and then into some sort of storage vessel. Such technique has been practiced for centuries (Biswas and Mandal, 2014), RWH is one of the simplest and oldest methods of self- supply of water for households, residential and household-scale projects, usually financed by the user (RWSN, 2017). Among the various alternative technologies to augment freshwater resources, rainwater harvesting is a decentralized, environmentally sound solution, which can avoid many environmental problems associated with centralized, conventional, large-scale project approaches (Andrew, 2003; Shittu et al., 2015). Also, it uses simple technologies that are inexpensive and easy to maintain. Hence, rainwater harvesting is becoming a viable source of water supply as it has become a norm in many countries such as Germany and Australia (FAQ, 2021). RWH can be considered as a viable technology in Nigeria especially in an urban setting such as Benin City as it is located within the rainforest zone of Nigeria. However, this technology is not often considered by planners, engineers and builders because of lack of information. Although, studies on rainwater harvesting in Nigeria have evaluated its performance (Tobin et al., 2013), investigated its potential to increase water supply in both north eastern and south western Nigeria (Ishaku et al., 2011; Shittu et al., 2015). However, little or no documentation is available on its potential to increase water supply in south-south Nigeria. Therefore, this study aimed at designing and constructing a RWH system for securing domestic water supply in Benin City. This will contribute to solving the problem of water crisis in Nigeria.

2. Materials and Methods

2.1 Study Area

Ovia North-East Local Government Area has its headquarters in Okada town and it has an area of 2,301 square kilometres (Akinbo and Okaka, 2010). It is bounded by longitude 5° 45' and 6° 15' east and latitude 5° 15' and 6° 45' north of the central province of Edo state. The main river, Ovia River flows through all the communities in the LGA (Akinbo and Okaka, 2010). The Local Government Area (Ovia North East) is situated in Benin City and

Benin City is located within the rainforest zone of Nigeria with mean annual rainfall in the range of 1500 mm to 2500 mm and the mean monthly temperature varying from 25°C to 28°C (http://www.edoworld.net/Edotourismweather.html). The Benin Region is underlain by sedimentary formation of the South Sedimentary Basin (Ikhile, 2016) and it constitute part of the Benin formation which is made up of over 90% massive, porous, coarse sand with thick clay/shale interbeds having high groundwater retention capacity (Adegbite et al., 2018). The geology is generally marked by top reddish earth, composed of ferruginized or literalized clay sand (Ikhile, 2016). Benin City has two distinct seasons. These are the wet (rainy) season and the dry season. The rainy season occurs between the months of March and October with a short break in August. The dry season on the other hand lasts from November to February with dry harmattan winds between December and February, but with the effect of global warming and climate change, rains have been observed to fall irregularly almost in every month of the year with double peak periods in July and September (Rawlings and Ikediashi, 2020). At present the population of Benin City is estimated to be about 1.75 million (projected from 2015 population figures).

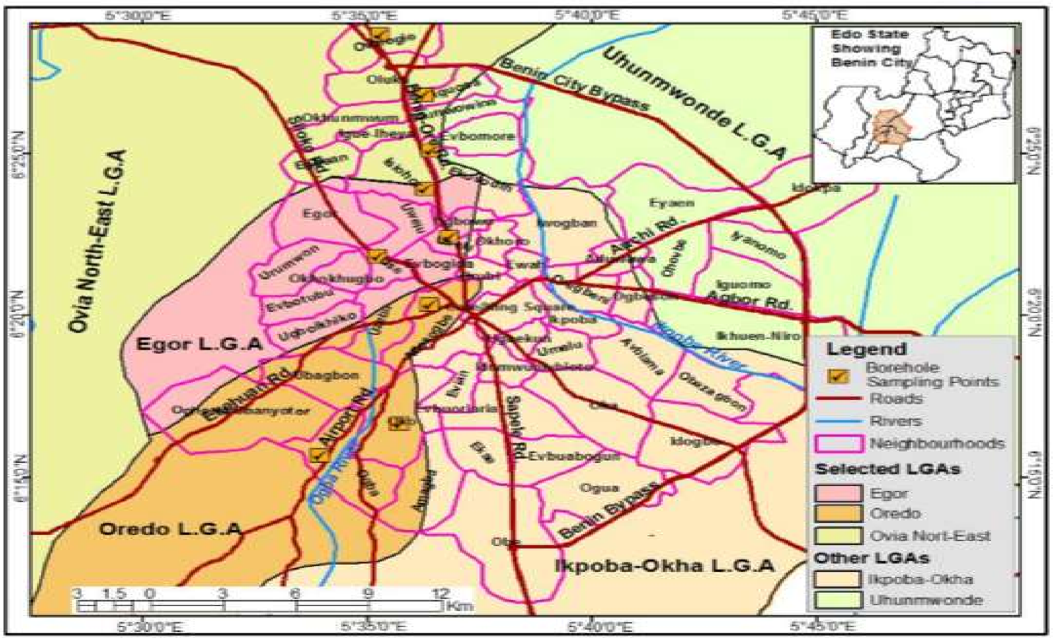

Figure 1: Map of Benin City Showing Ovia North-East LGA and other Local Government Areas (Sources: Ogbeifun et al., 2019)

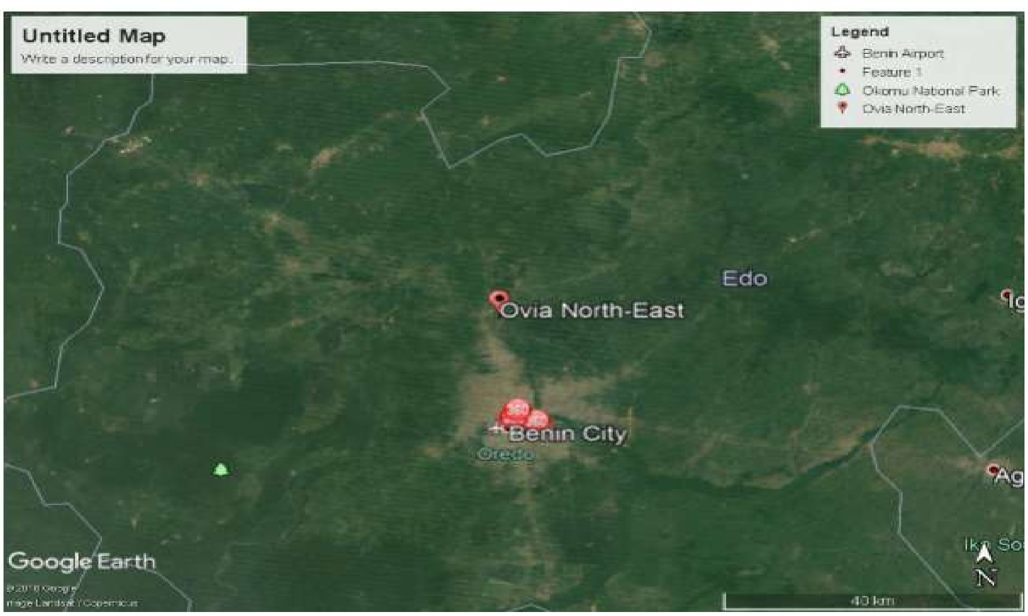

Figure 2: A Map Showing the Location of Ovia-North East LGA (Source: Google Earth)

2.2 Methodology

In this study, field data were used for the design of the RWH system and a prototype RWH system was constructed for pilot trials using the field data as the baseline data. A building roofed with a Corrugated Metal (Zinc) Sheet was used for this study. Monthly rainfall data (from 2002 to 2016) were collected from Nigerian Meteorological Agency (NIMET) and analysed using arithmetic mean. The RWH system consists of three basic components namely: Roof Catchment, Collection System (Gutter and Down pipe) and Storage tank. The RWH system was designed based on the following design criteria:

i. *Determination of Domestic Water Demand*

Harvested rainwater can be used for a variety of purposes (such as drinking, cooking, washing, bathing, flushing of toilet etc.) which are considered in this study. According to Lee et al. (2000) as cited by Shittu et al. (2015), the water demand for meeting the aforementioned purposes per person per day are as follows:

Table 1: Water Demand for Various Water Uses (Adapted from Shittu et al., 2015)

Uses	**Quantity (Litres, L)**
Cooking	10
Washing and Bathing	50
Flushing of Toilet	20
Other needs	10

According to Howard and Bartram (2003), recommended water intake for adult male and female is as follows;

Male = 2.5 L/day

Female =2.2 L/day

Hence, average water intake (drinking) for adult is estimated to be 2.4L/day. Therefore, the total water demand (for cooking, washing and bathing, flushing of toilet and drinking) is estimated to be 82.4L/person/day. The studied household contains five persons, thus the daily water demand for the studied household is estimated as $82.4 \times 5 = 412$L. Assuming four months as the longest average dry period the storage requirement for the aforementioned purposes is $412 \times 30 \times 4 = 49{,}440$L.

ii. *Runoff Coefficient (RC)*

Runoff coefficient expresses the relationship between precipitation and runoff. It is the ratio of the volume of water that drains off the surface to the total volume of precipitation that is received during a certain period (Bedient et al., 2013; Biswas and Mandal, 2014; Júnior, 2015). Runoff coefficient may vary according to the roof material, slope of the roof, soil type, vegetation, permeability etc. (Numes et al., 2011; Biswas and Mandal, 2014). The runoff coefficient was determined based on the roof material as indicated in Table 2.

Table 2: Runoff Coefficient for Traditional Roofing Materials (Adapted from Biswas and Mandal, 2014)

Type of Roof Material	**Run off Coefficient**
Galvanised Iron Sheet	>0.9
Corrugated Metal Sheet	0.7-0.9
Tiles	0.8-0.9
Concrete	0.6-0.8
Brick Pavement	0.5-0.6
Rocky Natural Catchment	0.2-0.5
Soil with Slope	0.0-0.3
Green Area	0.05-0.1

Based on Table 2, a runoff coefficient of 0.9 was adopted for this study.

iii. *Catchment Area*

The catchment area is the first point of contact for rainfall, thus a vital component of RWH system. For vast majority of domestic RWH systems, the catchment area is the roof surface. The roof surface maybe constructed of various different materials which include but are not limited to, Galvanised Iron Sheet, Corrugated Iron Sheet, Corrugated Plastic, Concrete and Tiles (Biswas and Mandal, 2014). The roof catchment area is already available for a building with an impermeable roof. Hence, a bungalow roofed with a Corrugated Metal (Zinc) Sheet and having an approximate size of existing roof catchment area to be 120m^2 (as measured directly from the building) was used as a reference for constructing the prototype RWH system. Thus, the prototype roof catchment area was estimated to be one tenth of 120 = 12m^2. About 40 m^2 out of the catchment area (120m^2) was considered to be guttered and this was divided into two sections; both sections have area of 20m^2 respectively. These sections of the catchment with total area of 40m^2 were used as a reference for that of the prototype building. Thus, the prototype roof catchment area was divided into two sections with both sections having area of 3m^2 respectively and thus total area of 6m^2 was guttered and used for holding rainwater.

iv. *Analysis of Rainfall Data*

Monthly rainfall data for Benin City for a period of 15years (from 2002 to 2016) were analysed using arithmetic mean to get the average annual rainfall for the period and this was estimated to be 2943mm/year.

v. *Potential Quantity of Rainwater that can be Harvested from the Roof*

The quantity of rainwater that drains from a roof is usually estimated using the following equation (Thomas and Martinson, 2007; Biswas and Mandal, 2014):

$$Q = RC \times R \times A \quad \ldots\ldots (1)$$

Where:

Q = Quantity of that runs off the roof (L/yr)

$RC =$ Runoff Coefficient (for Corrugated Metal Sheet) = 0.9

R = Mean Annual Rainfall (mm/yr) = 2943mm/yr

A = Roof Area (m^2) =120m^2

The quantity of rainwater that drains from the roof is 317.844m^3/yr (317,844 L/yr). Hence, the amount (volume) of water that can be harvested is 868.43 L/day. However, not all the catchment area was considered to be guttered, only 40m^2 of the roof was used. This amounts to 33% of the total capacity. Therefore, actual supply = 0.33 x 868.43 = 286.58 L/day.

Assuming eight months as the rainy season, thus the amount of rainwater that can be harvested during this period is 286.58 × 30×8 = 68,779L which is more than enough for storing the required amount (49,440) to be used during the dry season for drinking, cooking, washing, bathing, flushing of toilet.

vi. *Dimensions Adopted for Construction of the Prototype Building*

The following major dimensions were adopted (based on the reference building) for constructing the prototype building;

Length of the Building = 3m

Breath/Width of the Building = 2m

Height of Building = 1.5m

Roof Area (Corrugated Zinc Roof) = 12m^2

2.3 Components of Rainwater Harvesting (RWH) System

As mentioned earlier, the RWH system has three major components, namely: Catchment Area, Supporting Collection System and Storage Tank.

i. *Catchment Area*

As mentioned earlier, an approximate size of the existing roof catchment area which was used as a reference for constructing the prototype RWH system is 120m^2 (as measured directly from the building). Thus, the prototype roof catchment area was estimated to be one tenth of 120 = 12m^2 and about 6m^2 was guttered and used for holding rainwater. Two sections of the roof catchment area of 3 m^2 respectively were used.

ii. *Collection System*

The harvested rainwater from the roof is conveyed to the storage reservoir or tank via a system of gutter and pipes. Gutters are meant to carry the harvested rainwater from the roof securely before it is transferred to a downpipe through which the water would reach the storage unit. The water is channelized through these gutters to prevent water ingress into the fabric of the building. Otherwise, water flowing over the exterior walls and their foundations can lead to dampness, which will further weaken the structure and provide a favourable environment for growth of molds and fungi. Hence, a well-designed gutter system can enhance the durability of a house. In this study two sections of the roof catchment area were guttered, the gutter which was constructed of Corrugated Metal (zinc) Sheet was installed beneath the roof edge of the roof catchment sections area and was supported by brackets or metal hangers. These brackets or metal hangers were mounted first to the fascia board before the gutter was installed. This was done in order to keep the gutter firmly in position. A metal net screen was placed at the entrance of the water collection system in order to keep small as well as large debris at bay. Pipes are used to channel the harvested water from the gutter directly to the storage reservoir or tank. A polyvinyl chloride (PVC) down pipe was installed from the entrance of the water collection system to the storage tank. The downpipe was extended with a Tee joint pipe fitting to serve as a roof washer/flushing system. A roof washer/flushing system remove the initial water harvested which is most likely to be contaminated. Below the Tee joint is a ball-like valve that can open and close to flush out the dirty water during the first major downpour without getting into the system. Thus, making the RWH system a self-washing system. Tee and elbow joints pipe fittings were used to connect the down pipe to a filter with granular activated carbon and fine sand to help treat the harvested water as it goes into the storage tank. The filter was design and fitted in such a way that it can easily be maintained (replaceable).

iii. *Storage Tank*

The storage tank is often the most visible or recognizable component of a RWH system. It is where the captured rainwater is diverted to and store for later use. Hence, it is paramount that the initial rainwater can be easily discharged outside the storage tank through flushing system (Biswas and Mandal, 2014). The main goal of the storage tank is safety (Texas A &M Agrilife Extension, 2022). It should store water that is safe to use and should be secure so that children or animals cannot access the tank. In this study, two plastic drums of 100L capacity each were used to store the captured rainwater. Each drum was placed at the guttered sections respectively. Each drum has an outlet which was fitted with a tap (15cm above the drum floor) for collecting water. The tap was fitted in such a way that it can be detached easily from the drum during maintenance. The drums were placed on a rectangular shaped platform which is about 2cm above the ground so that the water can easily be fetch from the tap. It was ensured that the drum lids were tightly fitted to prevent evaporation and mosquito breeding and also to keep insects, birds, lizard from entering the drums (Biswas and Mandal, 2014; Shittu et al., 2015).

2.4 Laboratory Analysis of the Harvested Rainwater

Harvested rainwater sample was collected from each drum using a 75cl plastic bottle and transported to the laboratory (Martlet Environmental Research Laboratory Limited, Benin City, Nigeria.) for analysis. It was ensured that the sample bottles were properly cleaned and sterilized before use. The samples were analysed for a selection of thirteen parameters namely; pH, Electrical Conductivity (EC), Temperature, Turbidity, Total Dissolved Solids (TDS), Chloride (Cl), Ammonium Nitrogen (NH_4N), Nitrite (NO_2^-), Nitrate (NO_3^-), Iron (Fe), Zinc (Zn), Copper (Cu) and Coliforms Count (Col.), according to the techniques describe by the American Public Health (APHA 1985, 1995, 2005 and 2012). The methods adopted for analysing the samples parameters are indicated in Table 3.

Table 3: Analytical Methods for Harvested Rainwater Samples

Parameters	**Analytical Methods**
pH	Flame Photometric Method
Electrical Conductivity (EC)	Flame Photometric Method
Temperature	Thermometer Method
Turbidity	Spectronic 20 D^+ Spectrophotometry Method
Total Dissolved Solids (TDS)	Flame Photometric Method
Chloride (Cl)	Titrimetric Method
Ammonium Nitrogen (NH_4N)	Titrimetric Method
Nitrite (NO_2^-)	Spectrophotometry Method (Atomic Absorption Spectrophotometer)
Nitrate (NO_3^-)	Spectrophotometry Method (Atomic Absorption Spectrophotometer)
Iron (Fe)	Spectrophotometry Method (Atomic Absorption Spectrophotometer)
Zinc (Zn)	Spectrophotometry Method (Atomic Absorption Spectrophotometer)
Copper (Cu)	Spectrophotometry Method (Atomic Absorption Spectrophotometer)
Coliform Count (Col.)	Membrane Filtration Method

3. Results and Discussion

The results obtained from this study are presented and discussed in the sub sections below.

3.1 Rainfall Seasonal Variation and Rainfall in Benin City

The results obtained from the analysis of monthly rainfall data for Benin City for a period of 15years (2002- 2016) are indicated in Figure 3 and 4. Figure 3 shows the average monthly rainfall data (mm) for Benin City (2002-2016) while Figure 4 shows the Average Annual Rainfall Data (mm/year) for Benin City (2002-2016).

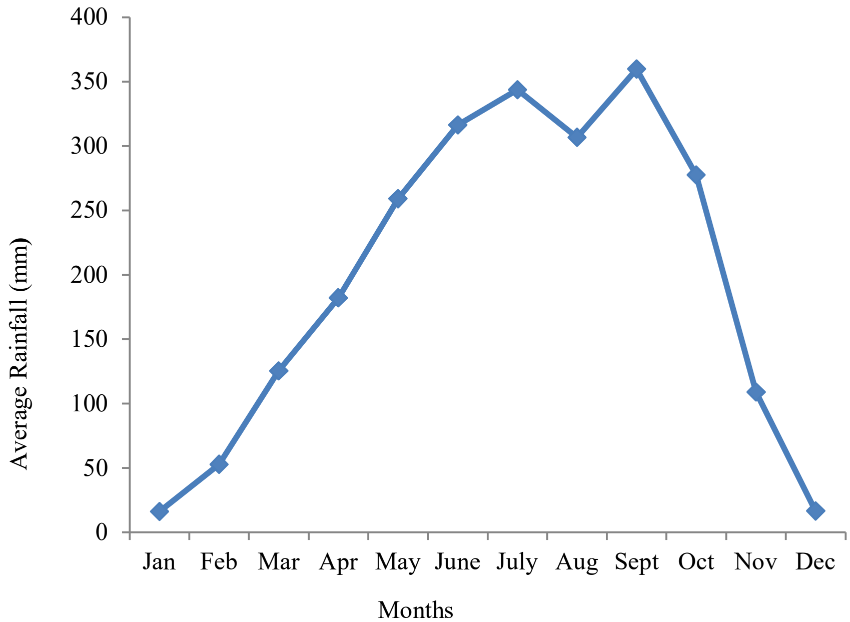

Figure 3: Average Monthly Rainfall Data (mm) for Benin City (2002-2016)

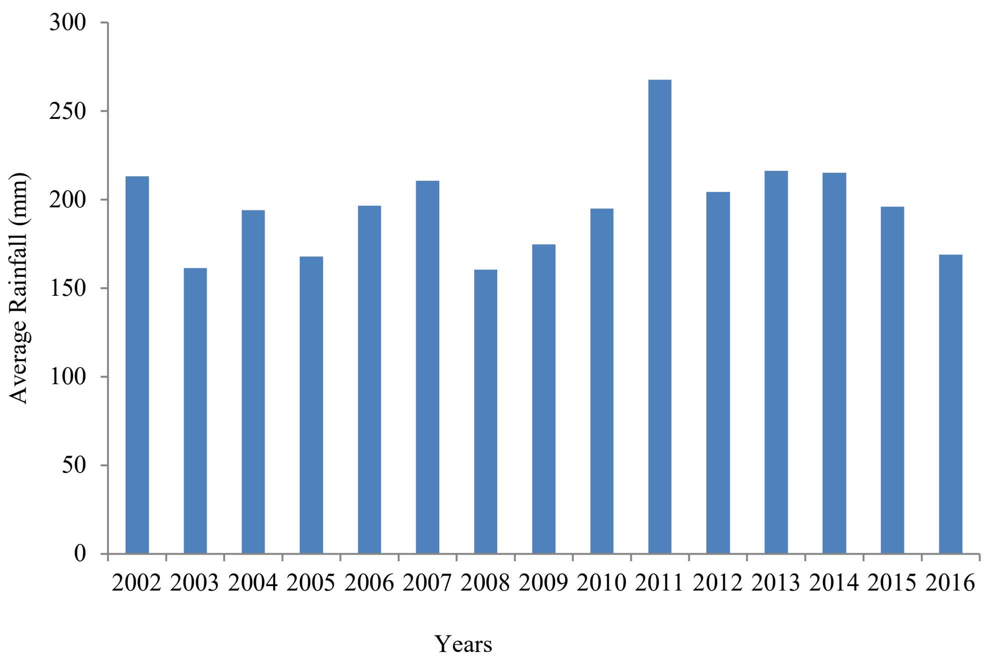

Figure 4: Average Annual Rainfall Data (mm/year) for Benin City (2002-2016)

From Figure 3, result indicated that the average monthly rainfall (mm) for Benin City (2002-2016) was lowest in January and December which is in accordance with previous work done by Adejuwon (2012) and Rawlings et al. (2020) in Benin City. There was a monotonic increase in rainfall at the station (Benin City) until August when there was a limited reduction in the amount of rainfall. This reduction might be attributed to the short dry season which occur in August and often referred to as the “August break” (Adejuwon and Odekunle, 2006; Gbuyiro and Adefisan, 2007; Adejuwon, 2012; National Bureau of statistics, 2012; Rawlings et al., 2020). The period of July/September marks the peak period of rainfall in the station, thus Benin City received heavy rainfall during the rainy season. In September there was an increase in rainfall followed by a decrease till December. By this time, the entire Benin City is experiencing the dry harmattan air from the Sahara Desert. Hence, the climate of Benin City experiences short dry season (August break). Result from Figure 4 shows that there was high amount of rainfall during the periods considered (2002-2016) and this is indicating that significant amount of rain water can be harvested during the rainy season.

3.2 Rainwater Harvesting (RWH) System

The prototype RWH system is presented in Figure 5 and Plate 1. Figure 5 shows the schematic diagram of the prototype RWH system and storage while Plate 1 shows the RWH system components.

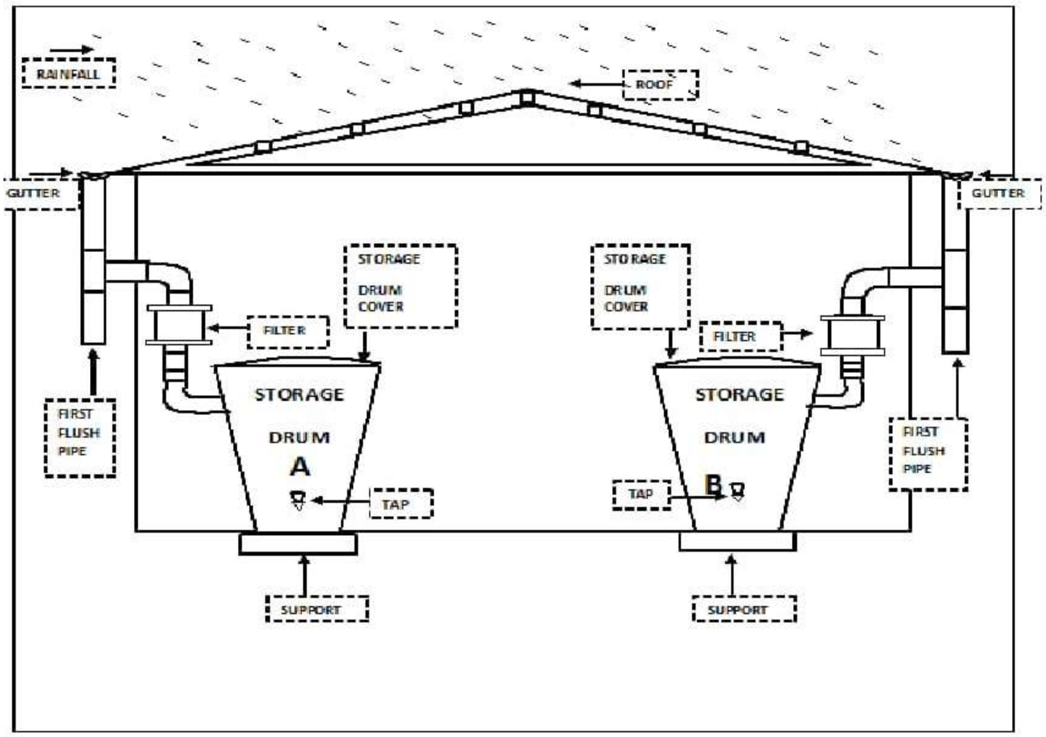

Figure 5: Schematic Diagram of the Prototype RWH System

Plate 1: The Prototype RWH system components

The prototype RWH system with a guttered roof area of 6m^2 was able to harvest about 45litres of water per day (after a heavy down pour that lasted for about 90 minutes) in April, 2022. Considering a real life situation with a guttered roof area of 40m^2 (as earlier mentioned), the system will harvest; $\left(\frac{40}{6}\right) \times 45 = 300$ L/day which is not too far from the calculated actual supply/harvested (286.58 L/day). As earlier mentioned, assuming eight months as the rainy season, the amount of rainwater that can be harvested during this period is 300 × 30×8 = 72, 000L which is more than enough for storing the required amount (49,440L) to be used during the dry season. This result is in agreement with those of Biswas and Mandal (2014) and Shittu et al. (2015) where the amount of rainwater harvested exceeded that of the required storage. The required reservoirs or tanks to store the harvested rain water (72,000L) will be of about 75m^3 capacities.

3.3 Harvested Rainwater Quality

The result of physicochemical analyses of the harvested rainwater samples is presented in Table 4.

Table 4: Physicochemical Characteristics of the Harvested Rainwater Sample

Parameter	Harvested Rainwater (Sample A)	Harvested Rainwater (Sample B)	Mean	WHO (2011)	NSDWQ (2015)
pH	7.5	7.4	7.45	6.5-8.5	6.5-8.5
EC (µS/cm)	189	188	188.5		1500
Temperature	28.7	28.7	28.7	30	Ambient
Turbidity (NTU)	0.1	0.1	0.1	5	5
TDS (mg/l)	94	92	93	N/A	500
Cl (mg/l)	107.3	106.4	106.85	250	250
NH_4N (mg/l)	0.291	0.290	0.2905	N/A	0.5
NO_2^- (mg/l)	0.077	0.076	0.0765	3	0.2
NO_3^- (mg/l)	0.868	0.866	0.867	50	50
Fe (mg/l)	0.111	0.110	0.1105	0.3	0.3
Zn (mg/l)	0.239	0.237	0.238	N/A	3
Cu (mg/l)	0.063	0.062	0.0625	2	1
Col (Pt Co)	0.2	0.1	0.15	0	0

Sample A=Rainwater from Drum A; Sample B= Rainwater from Drum B; WHO =World Health Organisation;

NSDWQ = Nigerian Standard for Drinking Water Quality

Results from Table 4 shows that all parameters examined were below WHO and NSDWQ acceptable limits for drinking water standard except for coliform bacteria and that there is no significant variation in the parameters from sample A and B. This is an indication that the filter (made with activated carbon and fine sand) connected to the downpipe may have greatly improved the quality of the harvested rainwater. Studies have reported that activated carbon and sand are effective at removing contaminants from water (Hamdaoui and Naffrechow, 2007; Cheng et al., 2015; Tamanna et al., 2016).

Although, the mean Cl value (106.85 mg/l) was below the acceptable limit of 250 mg/l (WHO, 2011 and NSDWQ, 2015), but among the inorganic ions, Cl was the most abundant followed by NO_3^- (0.867 mg/l), NO_2^- (0.0765 mg/l) and NH_4N (0.2905 mg/l). The high concentration of Cl ion may have been acquired from the large bodies of Southern Nigeria Sea. Among the metals, Zn has the highest concentration with mean value of 0.238 mg/l followed by Fe (0.1105 mg/l) and Cu (0.0625 mg/l). All these values are well below the acceptable limits for drinking water. The high levels of Zn in the harvested rainwater might be attributed to the roofing material (Fewkes, 2012). According to Abdullah et al. (2022), zinc-based roofing material undergoes chemical reaction with the presence of oxygen in the atmosphere to form zinc oxide and zinc hydroxide if expose to moisture. These results are in consonance with those of Abdullah et al. (2022) where it was reported that the rainwater harvested from a zinc-based roof contain chloride ion as the most abundant inorganic ion and zinc as the most abundant metal.

The mean coliform count (015pt.co) was above the acceptable limit of 0 pt.co (WHO, 2011 and NSDWQ, 2015). The presence of coliform bacteria in the harvested rainwater is implying that the water is contaminated with pathogens and this might be attributed to the roof catchment area which may have been contaminated with bird or other animal faces (Rahman et al., 2014). Although minimum level of coliform bacteria was observed, however pure water should be free from all kinds of coliforms. Hence, a disinfectant (such chlorine) should be added to the harvested rainwater to sterilise it.

4. Conclusion

This study has assessed the viability of RWH and its suitability in domestic purpose in Ovia-North East LGA of Benin City. A prototype RWH system (mini system) was constructed for small household using locally available materials and it was found to be effective. Results showed that with a roof area of $40m^2$, $75m^3$ reservoirs or tanks capacity will be required for dry period. Hence, the amount of rainwater that can be harvested in the rainy season and stored will be more than enough to serve a 5-membered household throughout the whole dry periods of the year. The physiochemical characteristics of the harvested rainwater revealed that all parameters analysed were within acceptable limits (WHO and NSDWQ) except for coliform bacteria. Although minimum level of coliform bacteria was observed, however pure water should be free from all kinds of coliforms, thus addition of a disinfectant (such as sodium hypochlorite solution as suggested by Shittu et al., 2015) to the harvested rainwater is required to further improve it quality for domestic use. Also proper maintenance of the catchment area and storage containers (tank or drum) could eliminate the presence of coliform bacteria and make rainwater safe for domestic purposes. Therefore, RWH can serve as an alternative and viable source of water supply which will help to reduce problems related to water scarcity and as such improve the standard of living of the people.

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