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Assessing Rainwater Harvesting Potential in Nigerian Secondary Schools– A Case Study of Government Girls Secondary School, Dutse, Abuja

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Abstract The objective of this study is to investigate the applicability of rainwater harvesting to provide potable water in Nigerian academic institutions with the view of alleviating the water supply poverty in the country. Water supply generally requires long term planning and huge investments. Rainwater harvesting has the potential to supply water to the medium and low income population in Nigeria at an affordable rate. Total water demand and potential water harvest for Government Girls Secondary School, Dutse, Abuja was determined from roof area of 52944m^2, the student population of 1808 and water use of inhabitants in developing countries of 72 litres per capita day. The potential water that can be harvested was found to be 58,830m^3 compared to a total demand of 35,150m^3. This indicates a potential for rain water harvesting in academic institutions across Abuja region of Nigeria.

Keywords Rainwater harvesting, academic institutions, Abuja-Nigeria, water supply, water demand

1. Introduction

Rain water harvesting is the process of collecting natural precipitation for beneficial use. The process comprises approaches to induce, collect and store runoff for various purposes such as irrigation, groundwater recharge, livestock, domestic use, gardens and so on. Water supply augmentation in the case of inadequate water supply requires several years of planning huge capital investments to make water available. Rainwater harvesting is an economical small-scale technology that has the potential to augment safe water supply with least disturbance to the environment, especially in the drier regions. Furthermore, it is de-centralized and independent of governmental maintenance and operation, making it crucial for augmenting water supply.

In Nigeria, less than half of the population has reasonable access to reliable water supply [1]. Nigeria is the most densely populated country in Africa with approximately 184 million inhabitants and a growth rate of 2%. Despite substantial progress in developing policies and strategies in the water supply sector, the country is inundated with a very low access to improved sanitation due to poor operation and maintenance linked to weak and inefficient institutions and persistent implementation failure [2]. In addition, urban services will face serious challenges in the near future to meet the fast growing needs of estimated urban population growth [3]. The use of contaminated drinking water and poor sanitary conditions result in increased vulnerability to water-borne diseases. In some parts of Yenogoa, approximately 30% of its populace use below 20 liters per person per day of water attributed to high cost water compared to the nations minimum wage [4]. This is approximately 730m^3 per person per year and falls within the sphere of water scarcity (< 1000m^3 per person per year).

Clean fresh water is a vital natural resource essential for life to prevent communicable diseases and to maintain healthy life [5]. Groundwater and rivers are the major fresh water resources [5]. Globally, the world is facing significant problems in maintaining reliable water supplies due to growing populations, climate change and limited cost effective water supply options [6].

Increase in human population and environmental degradation in many countries of the world especially the developing countries are reducing human access to safe potable water. Based on the global population trend, it has been observed that the developing countries will contribute more to human population in the years to come [7]. Similar to many developing countries, Nigeria is unable to satisfy its domestic water needs and only 47% of the total population have access to water from improved sources in 2007 [8]. Also, approximately 47 million Nigerians rely on surface water for domestic use despite pollution discharge from various sectors [9]. One of the main priorities of the UN summit in New York (2015) is access to clean water and sanitation for all by 2030 as the goal 6 of the 17 Sustainable Development goals [9]. It requires measures such as adopting rainwater harvesting as part of an integrated approach to ensure safe and affordable water [9].

Human use accounts for over half of the accessible fresh water runoff globally [10]. 768 million people in the world lack access to an improved source of drinking water while 2.5 billion people live without basic sanitation facilities that live predominantly in developing countries such as Nigeria [11-12]. The lack of basic sanitation and access to drinking water prevents their citizens from living a healthy and productive life and also resulting in huge annual economic losses [13]. Furthermore, per capita fresh water will decrease due to population growth while climate change is transforming the hydrological cycle intensifying precipitation and evapotranspiration and subsequent effects on water quality.

Rainwater harvesting reduces urban flooding and prevents runoff from going into sewer systems, thereby reducing loads on treatment plants [14-15]. In addition, it counters the vulnerability of centralized supply from cut-off disasters and destruction during acts of war [16].

Application

Rainwater harvesting is a mature technology employed for survival from the late Neolithic to early bronze age in the semi-arid regions of Mesopotamia (Iraq & Jordan) [17]. It was practiced by the Ur people as far back as the 4500 BC to provide urban dwellers with potable water supply. By 3000BC, it was further adopted for irrigation, potable and bathroom use in Minoan Crete, Indus valley (Afghanistan, Pakistan and India), China and India [14, 17]. It was also identified in 1700BC in the palace of Knossos (Crete). The Roman were adept at the science and art of rainwater harvesting since the early Roman period [15]. Rain water harvesting using open and closed water cistern was identified in Turkey before 1000AD. The technology became extinct during the industrial revolution as a result of demand for huge amounts of water and increased urbanization replaced by centralized water treatment and supply. It is emerging as a popular technology to augment water supply in both developing and developed countries [17].

Rainwater harvesting from roofs or impervious surfaces has widely been used to provide urban dwellers with potable water supply in many parts of the developing world [18-21]. It is adopted on a large scale in India because it is part of the policies in some states (Centre for Science and Environment, 2010). In certain rural areas of Taraba and Gombe states of Nigeria, 3% of the inhabitants harvest rainwater [1]. Meanwhile, 50% of the population rely on natural water bodies and hand dug wells that are vulnerable to drought. In addition, these areas have sufficient rainwater to harvest. Rainwater harvesting is a traditional technology in some parts of Zambia mainly by placing buckets under roof gutters with a few proper systems installed in schools [21].

The objective of this study is to investigate the applicability of rainwater harvesting to provide potable water in Nigerian academic institutions with the view of alleviating the water supply poverty in the country. This is to ensure the basic requirements of water supply are met. The application of rainwater harvesting will mitigate the contribution of the institutions area to urban floods experienced in certain parts of the country; reduce erosion potential of rain water and mitigate overloading of the sewage treatment plants.To achieve this aim, rainwater pattern and water demand of the study area and existing available catchment area was determined.

In certain rural parts of the country – Gombe and Taraba, 3% of the population harvest rainwater in an area where more than 50% of the population relies on natural water bodies and hand dug wells for water [1]. These types of water supply are prone to drought while the communities' have sufficient rainwater to harvest. Up till 2010, there has been a dearth of data on rainwater harvesting for domestic use in Nigeria [22].

Quality of Harvested Rainwater

Some studies indicate water from rooftops as meeting international guidelines [21, 23-24] while others have found such water with contaminants exceeding the international limits [25-26]. The quality of the rain harvested water depends on the type of catchment area, the type of water tank, handling of water and characteristics of area under consideration such as proximity to pollution source and topography [23, 24]. Measures to combat contamination include regular cleaning of storage facility and catchment area, use of filters, addition of disinfectant and flushing or diverting the first millimeters of rain [23, 27].

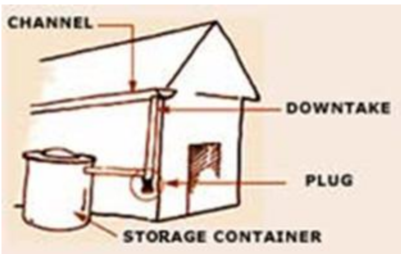
Quality of rainwater is evaluated by considering relevant water quality parameters [28]. These parameters include turbidity; pH; total dissolved solids; biochemical oxygen demand (BOD); total coliform; faecal coliform; heavy metals – iron, calcium, zinc, magnesium and lead; & ions – fluoride. pH and faecal coliform are of particular interest due to exposure of rainwater to atmospheric contamination; settled particles and bird droppings on roof catchment.

Components of Rainwater Harvesting System

Rainwater harvesting is made up of three basic sub-systems- a catchment system, a delivery system (pipes, filters and gutters), and a storage system [20, 29]. The catchment is the surface which directly receives rainfall and provides water to the system. It is generally a roof made of reinforced cement concrete (RCC), galvanized iron or corrugated sheets. It can also be paved areas like a terrace or courtyard of a building, or an unpaved area like a lawn or open ground [14].

Gutters are the channels around the edge of the roof to collect the rainwater for transportation. They can be semi-circular or rectangular. Gutters are sized according to the highest intensity rainfall with a 10-15% factor of safety (CSE, 2017).

The conduit is made up of pipelines or drains that carry rainwater from the catchment or rooftop area to the harvesting system. Conduits can be of any material like polyvinyl chloride (PVC) or galvanized iron (GI), materials that are commonly available. A coarse mesh is used at the conduit entrance to prevent debris.



Source: CSE

The storage facility options consist of cylindrical, rectangular and square shapes; reinforced cement concrete, (RCC), Ferro cement, masonry, plastic (polyethylene) or metal (galvanized iron) sheets based on material of construction. Based on position of tank and depending on space availability these tanks could be constructed above ground, partly underground or fully underground.

2. Methodology

The amount of rainwater that can be harvested is a function of area of plot or catchment area, average annual rainfall and an assumption of percentage of effective harvest [15, 30-31] as shown in Equation (1).

$$Harvested\ water = catchment\ area\ X\ average\ annual\ rainfall\ X\ efficiency\ factor\ or\ runoff\ coefficient \quad (1)$$

The catchment area (an impervious surface) is the roof where water can be collected, was measured directly in this study. The rooftop of the main buildings in the school, made up of three (3) laboratories, four (4) dormitories, a dining hall, a multipurpose hall, the school library, the art hall, the school clinic, the worship centre and seventeen (17) classes were employed as catchment area. A measuring tape was used to obtain the area.

Runoff coefficient for any catchment is the ratio of the volume of water that runs off a surface to the volume of rainfall that falls on the surface. The run-off coefficient accounts for water losses due to surface material texture, evaporation, losses occurring in gutters, spouts and storage tanks, surface cleaning, inefficiencies in collection process and losses due to wind direction and speed [15]. Various catchment types have different coefficients as shown on Table 1.

Table 1: Default Values for the Run-off Coefficient (Pacey, Arnold and Cullis, Adrian, 1989 in [31]

Type of Catchment	Coefficients
Roof catchment	
Tiles	0.8 – 0.9
Corrugated metal sheets	0.7- 0.9
Ground surface coverings	
Concrete	0.6 – 0.8
Brick pavement	0.5- 0.6
Untreated ground catchments	
Soil on slopes less than 10 per cent	0.0 – 0.3
Rocky natural catchments	0.2 – 0.5

The potential rainwater that can be harvested was compared to the estimated water demand of the boarding students in the institution.

2.1. Study Area

The study was carried out in Government Girls Secondary School (GGSS), Abuja. Abuja is the capital city of Nigeria situated on latitude 8° 25” and 9° 25” North of the Equator and longitude 6° 45” and 7° 45” East of the Greenwich. It is bordered to the North by Kaduna state, to the east by Nassarawa state, to the west by Niger state and to the south by Kogi state [32-33]. The key climatic parameter required to establish amount of rainwater that can be harvested is the annual rainfall [34]. According to the Koppen and Geiger classification, Abujas' climate is classified as Aw with an average annual temperature of 25.7 °C and approximately 1389 mm/y of average precipitation, where the annual total rainfall ranges between 1100mm to 1600mm [35-36]. The rainfall spreads across April to October [33].

2.2. Water Demand

The water demand of the study area was established using the population of the school students and per capita water requirement of inhabitants in developing countries. The average water use per capita per day in many cities and towns in developing countries across the globe range between 72 litres to 135 litres for pipe-connected buildings [37]. 72 litres average was identified in 7 townsin Cambodia. Meanwhile, buildings without piped water connections have a wide range of average water use from as low as 15 litres per capita in a day to 110 lpcd [37]. In addition to piped connections, a number of factors influence the water use rates including purchasing water from vendors, availability of private wells and obtaining water from public taps.

3. Result and Discussion

The potential annual average water that can be harvested from the total rooftop area of 52,944m^{2}is 58,830m^3 per annum according to Equation 1.

The potential water that can be harvested is based on a runoff coefficient of 0.8 adopted from the default coefficients presented of 0.7-0.9 for corrugated metal sheets [31] while an average annual rainfall of 1389mm/y was be adopted.

Table 2: Catchment Area of GGSS Dutse

Buildings	Catchment area (m^2)
Laboratories	795
Halls	6461
Dining Hall	1165
Multipurpose Hall	1068
School Library	540
School Clinic & Art Hall	584
Classes	42018
Mosque.	312
Total	**52,944**

Thetotal water demand of 1808 students of GGSS Dutse was found to be 35,150m^3 based on a per capita water use rate of 72 litres per capita day and an approximate number of days (285) spent in three (3) terms of the school year.

A comparison of the potential water harvest of 58,830m^{3}and total demand of 35,150m^3 indicates the viability of rain water harvesting as main or sole source of water supply in the Abuja region and areas with similar climatic conditions particularly rainfall pattern.

4. Conclusion

There is a huge potential for exploitation of rain water harvesting from rooftops in academic institutions across the Abuja region in Nigeria where the water that can be harvested at 58,830m^3 is surplus to requirement of 35,150m^3 for the case study area.

A similar assessment of rain water harvesting potential can be extended to other parts of the country with different rainfall patterns and rates.

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