IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES
ISSN PRINT 2319 1775 Online 2320 7876

Research paper © 2012 IJFANS. All Rights Reserved, UGC CARE Listed (Group -I) Journal Volume 11, Iss 7, July 2022

Assessing the Potential for Rainwater Harvesting

Puneet Agarwal, Assistant Professor,
Department of Mechanical Engineering, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India
Email Id- puneetagarwal007@yahoo.com

ABSTRACT: Rainwater collecting is one of the most promising methods for augmenting limited surface and subsurface water resources in places where the current water delivery infrastructure is insufficient to satisfy demand. One of the measures for minimizing the effect of climate change on water supply is rainwater collecting. Rainwater collection is excellent in Abeokuta due to the city's average annual rainfall of 1,156 mm. The intra-annual range was 0.7 to 1.0, whereas the inter-annual variability was 0.2. Each home may collect 74.0 m3 of rainwater each year. Annual water consumption for flushing, washing, and flushing was estimated to be 21.6, 29.4, and 21.6 m3 correspondingly. Except in November, December, January, and February, harvested rainwater in Abeokuta can meet family monthly water needs for toilet flushing and washing. If there is enough storage, the extra rainfall saved in September and October will enough to replace the short fall in the dry months. The opportunity for water conservation is greatest between June and September, which are the two rainiest months in Southwest Nigeria.

KEYWORDS: Climate, Collecting, Harvesting, Rainwater, Resources.

1. INTRODUCTION

One of the most basic human rights is to have access to safe and inexpensive water. Water is both a need for existence and a basis for every country's social and economic growth. Water is mostly utilized in the home, agriculture, and industry. Water availability at agricultural and industrial levels is largely a function of food production. The world's water supplies are under strain due to demographic, economic, and social reasons. Increased water demand and pollution were imposed on fresh water resources as a result of population dynamics, which are a consequence of growth, gender and age distributions, and migration. Water resources and their usage are also being impacted by changes and development in the global economy.

Similarly, societal factors in water resource problems include changes in lifestyle and individual perceptions of water resources, as well as changes in consumption rate and life pattern (WWAP 2009). Increased human population and environmental deterioration in many nations across the globe, particularly in developing countries, have reduced human access to clean drinking water in recent years. According to the global population trend, emerging nations will contribute more to the human population in the next years. Nigeria, like many poor nations, struggles to meet its household water requirements, with just 47% of the population having access to improved sources of water in 2007. If the copious rainfall in the nation, especially in southwest Nigeria, is properly harnessed, it would aid in resolving the country's chronic water shortage. This may be accomplished by using inter basin water transfer, a novel water resource management approach.

Rainwater harvesting effectively relieves strain on the public water delivery system, which is often inoperable owing to logistical and structural issues[1]–[5].

Scarcity is the world's most serious water issue. In developing nations, rising population and urbanization, along with climate change, may decrease urban water availability. UNEP has identified Nigeria as one of the 25 African nations that would face water shortage or stress by 2025. Despite the abundance of land and water resources accessible in different climatic zones, the nation is already experiencing water shortages in both urban and rural regions. This may be linked to rising human population and urbanization, pollution, insufficient infrastructure, climatic variability and change, poor water policy implementation, and financial mismanagement. Rainwater collecting for non-potable or irrigation purposes, as well as groundwater recharge, is increasingly being explored in many metropolitan areas due to rising water demand.

In the field of water resource management, rainwater collecting is not a new idea. It has existed for a long time, long before large-scale public water systems were introduced. In China, Brazil, Australia, and India, rainwater collection is encouraged and promoted. In New Delhi and Chennai, India, a rainwater harvesting system is required for a construction proposal to get permission from the local government. Rainwater has been shown to help buildings save potable water. Rainwater is used extensively in public facilities in Japan, London, and Berlin. Rainwater collecting has many advantages. It offers a free supply of water with only storage and treatment expenses, as well as supplementing restricted groundwater supplies and reducing storm water runoff. In urban areas, it lowers erosion and non-point pollution. Rainwater collecting offers soft, natural water that may be used for non-potable interior purposes. Rainwater may be used to make safe drinking water once it has been treated properly. Rainwater harvesting, in addition to its ability to produce large amounts of water, results in the collection of decentralized water, making it less costly than well digging and water delivery from public faucets. In every watershed system, rainwater may be utilized to reduce water loss and supplement water supply. Rainwater harvesting and other simple new solutions may reduce greenhouse gas emissions from water storage reservoirs and water treatment procedures, both of which contribute to climate change[6]–[10]. Despite the fact that rainwater accounts for more than 90% of surface water in Nigeria, data on available rainwater collecting for household use is few and poorly recorded, making impartial evaluation impossible. Similarly, no estimate has been made for the usage of rainwater for WC flushing and washing in any Nigerian city or area. Abeokuta is part of the Ogun-Osun River Basin and Rural Development Authority, which is situated in the humid tropical rainforest zone of Nigeria's southwest. The potential for home rainwater collecting in Abeokuta will be evaluated using rainfall data in this study. This would allow for a quantitative evaluation of the potential for rainwater collecting and potable water conservation measures that may be accomplished by utilizing rainwater for household purposes like toilet flushing and washing.

Abeokuta is situated in the sub-humid tropical area of Nigeria's southwestern region, between the latitudes of 75 and 20 degrees north latitude and the longitudes of 317 and 320 degrees east longitude. The average daily temperature is about 28 degrees Celsius. The city is mostly drained by the River Ogun, which follows a dendritic pattern. It has a population of 449,088 people and spans a physical area of 1,256 km^2. The water supply from the Ogun State Water Corporation (OSWC) is insufficient to satisfy the increasing population's daily residential and industrial needs, necessitating the development of other water sources. The new Abeokuta water system in Arakanga is designed to generate 163,000,000 L/day but only produces 80,000,000 L/day at the moment. Boreholes and shallow wells are utilized as alternative water sources throughout the city, although they are frequently contaminated. If properly harvested, rainwater may supplement existing water sources in Abeokuta and other parts of Nigeria.

Land-based and roof-based runoff collection are the two main types of runoff collecting following rainfall occurrences. The focus of this research is on Abeokuta's roof-based rainwater collecting potential. The quantity of rainwater that may be collected is determined by the roof area, rainfall depth, storage, and runoff coefficient, all of which are determined by the roof material and design. Monthly rainfall data from the Ogun-Osun River Basin and Rural Development Authority was examined for 26 years (1981–2006) to establish the rainfall pattern, average monthly and yearly rainfall, and wet and dry months for the years under study. A three-year monthly rainfall data set, mostly from 1981, 1993, and 2006, was displayed against their respective months to demonstrate the basin's bimodal rainfall pattern. The yearly rainfall totals were also plotted against the years in question. The intra-annual variability was calculated by calculating the monthly rainfall coefficient of variation, which is represented as:

$$CV = S_v/V_a$$

Where CV is the monthly rainfall coefficient of variation, S_v is the monthly rainfall standard deviation (in millimeters), and V_a is the monthly rainfall mean (in millimeters)

Similarly, the coefficient of variation of the annual cumulative rainfall for the years under study was used to estimate inter annual variability of the annual cumulative rainfall. The amount of rainfall that could be collected per home per month was calculated.

$$VR = (R*H_{RA}*R_C)/1000$$

Where VR is the monthly volume of rainwater per home (in cubic meters), R depth of monthly rainfall (in millimeters), `R_C runoff coefficient and HRA roof area (in square meters) (no unit).

In Abeokuta, the average roof area per house was calculated to be 80 m^2. In the humid tropics, the runoff coefficient for a hard roof is 0.85. According to current statistics, the typical household size in Nigeria is five people. According to the study, the average household water demand for WC flushing was 60 L per day, based on a daily use of 12 L per individual. These figures were gathered via a questionnaire given during face-to-face meetings with the homeowners.

This was used to determine the monthly flushing water requirement. The monthly water demand for laundry was also computed using a weekly water consumption of 150 L per home, and the monthly demand for laundry was estimated at 4.3 weeks/month (30 L per person for laundry per week). The total monthly and yearly water demand for flushing and washing were determined by adding the demand for flushing and laundry for each month and calculating the total for the year. The basic monthly balance was calculated by subtracting monthly water demand from monthly rainwater gathered, and is written as

$$W_a = Iv + Vc - Vu$$

Where W_a is the amount of water available and Vc is the amount of rainwater collected. Vc volume gathered Vu volume utilized Initial volume in storage

Using the demand method, the amount of rainwater needed to meet all of the anticipated requirements was calculated. The starting volume in storage was calculated using the monthly needs (1.80 and 2.45 m^3) for flushing, washing, and flushing combined. To get the amount needed for the dry months, the dry-month deficits were added to the starting volume.

1.1 Economic research:

The economic analysis findings for the basic scenario (WPE-S). Only one of the endeavors provided an economic advantage to the user under the circumstances specified in the WPE-S scenario. House R3a had a positive net present value (R$ 282.04), which is around 6% of the implementation cost. The IRR (7.7%) was higher than the minimal attractiveness rate, with a payback of 21.6 years, or 86% of the 25-year period. In a study of five cities in southern Brazil, found payback times ranging from 2 to 35 years, depending on water consumption and roof area.

For those instances when the rate was positive, the NPV may be positive if the discount rate was lower than the IRR, according to the definition of the IRR. The enterprise produced positive cash flows in these instances, but not enough to cover the opportunity cost of money. This is how the homes R2b (0.7 percent), R3b (0.6 percent), R4a (2.1 percent), R4b (1.5 percent), and R4c (5.6 percent) ended up. In terms of the NPV, the findings indicate that the house's overall demand is a critical factor in determining its economic viability. Starting at a total monthly demand of 10 m3, the NPV for each scenario, WPES (A), WPE-LD (B), and WPE-HD (C), rises with demand. This impact was observed for all homes with rising per capita demand.

The findings of the WPE-LD and WPE-HD scenarios backed up this theory. The NPV was negative in all instances under the WPE-LD scenario, when per capita demand was decreased by 30%. In most instances, the NPV rose with the 30% rise in demand from the WPE-HD scenario. The payback for residences R3a, R4a, and R4c was 11.9, 22.8, and 13.8 years, respectively, indicating the feasibility of these RWH systems. Furthermore, the IRRs of the R1a, R1c, R2b, R3b, and R4b homes were all positive.

The NPV was affected in a similar, but lesser, way by the rainwater percentage of total demand. Under certain instances, increasing rainwater usage increased NPV as compared to WPE-LR scenarios in WPE-HR and WPE-HR+ scenarios. The homes R3a and R4c had a positive NPV in these final scenarios. The repayment term for the R3a home was 15.9 (WPE-HR) and 15.2 years. In all situations, R4c had a payback of 24.4 years. The tariff structure of water collection affects the connection between NPV and demand. In the WPE-HD scenario of total demand growth, families having a monthly demand of more than 30 m3 had a positive NPV. For customers in the higher price categories, the stratified pricing structure results in larger marginal savings for every m^3 of water substituted with rainwater.

In the case of homes with lower demand, the opposite occurred. The total monthly water demand in homes R1b, R2a, and R2c is less than the social tariff's minimal usage of 10 m^3. Because the customer continues to pay a set price for the remainder of the drinking water used, the use of rainwater did not result in a reduction in the water bill in these instances. The cost of installation, as well as the cost of operation and maintenance, were all negative cash flows as a result of the deployment of RWH systems. As a consequence, the NPV had a loss larger than the implementation cost. When the percentage of drinking water replaced by rainwater was raised in one of the homes, something similar occurred. When the proportion of drinking water to be replaced by rainwater increased from 50% to 70% in instances R1b, R1c, R2c, and R3c, the NPV dropped from WPE-S to WPEHR. When the average drinking water usage in WPE-S was less than 10 m3 of the social tariff, this occurred.

As a consequence, increasing rainwater usage in WPE-HR and WPE-HR + did not result in a larger water bill savings, but rather an increase in treatment and energy expenses for the extra rainwater utilized. With the switch from WPE-HR to WPE-HR+, the scenario was replicated in houses R2b, R3b, R4a, and R4b. When non potable water demand rose, Silva observed comparable findings in Portugal, with the exception that the water tariff structure includes a variable component for all water consumption periods.

The majority of the projects' economic viability was affected by a change in the water rate. Rainwater harvesting was rendered impossible in all instances under the EA-LT scenario, which included a 30% reduction in tariff structure. Houses R3a and R4c showed a positive NPV for EA-HT. The IRR in these instances was 12.4 percent and 9.9 percent, respectively, with payback periods of 11.3 years and 14.8 years. Half of the RWH systems were economically feasible under the EA-HT+ scenario, with a 100% increase in the tariff structure, with NPVs above R$ 2000 in these instances. The NPV of homes with total water use more than 19 m3/month increases significantly, as shown in this data.

These findings suggest that a significant increase in water costs encourages high-demand families to install RWH systems even more, while having little impact on low-demand households. Amos et al. (2016) performed a study of the RWH system in Australia and Kenya, concluding that the most important economic element was the price of water conserved, which is on the rise. Water prices are projected to rise by 35 percent in Belém, Brazil, in 2017, making the RWH system more economically viable.

2. DISCUSSION

The author has discussed about the assessing the potential for rainwater harvesting, Rainwater collection is one of the most promising techniques for supplementing limited surface and subsurface water resources in areas where existing water delivery infrastructure cannot meet demand. Rainwater collection is one of the strategies for reducing the impact of climate change on water supply. Because to the city's average annual rainfall of 1,156 mm, rainwater collecting is good in Abeokuta. Intra-annual variability ranged from 0.7 to 1.0, whereas inter-annual variability was 0.2. Every year, each house may collect 74.0 m3 of rainwater. The majority of water is used in the household, agriculture, and industry. At the agricultural and industrial levels, water availability is mainly determined by food output. Water resources throughout the globe are under stress owing to demographic, economic, and social factors. Population dynamics, which are a result of growth, gender and age distributions, and migration, have placed increased water demand and pollution on fresh water resources.

3. CONCLUSION

The author has concluded about the assessing the potential for rainwater harvesting, A 26-year rainfall data for Abeokuta was acquired from the Ogun-Osun River Basin and Rural Development Authority, Abeokuta, in order to evaluate the potential of rainwater in Abeokuta. Monthly rainfall data for chosen years was displayed against the months in which they occurred. The total rainfall for each year was also plotted against the years. Inter annual and intra annual changes in rainfall were calculated using the data. The home water consumption for washing and flushing was calculated on a monthly and yearly basis. Tank sizes were developed and recommended based on demand and practicality.

Rainwater collecting systems may be used to supply water for non-drinking uses. If properly harnessed, rainwater use would result in substantial potable water savings in Abeokuta, Nigeria, and many other areas of the globe. The country's existing water constraints during the dry season will be alleviated by the plentiful rainfall available during the rainy season. With enough storage, collected rainwater can enough for non-potable home water needs including vehicle washing, cleaning, and a variety of other tasks. The availability of space and the cost of storage tanks will determine the viability of rainwater collecting in Abeokuta and other comparable towns.

REFERENCES

[1] S. Musayev, E. Burgess, and J. Mellor, “A global performance assessment of rainwater harvesting under climate change,” *Resour. Conserv. Recycl.*, vol. 132, no. August 2017, pp. 62–70, 2018.

[2] B. Helmreich and H. Horn, “Opportunities in rainwater harvesting,” *Desalination*, vol. 248, no. 1–3, pp. 118–124, 2009.

[3] N. García Soler, T. Moss, and O. Papasozomenou, “Rain and the city: Pathways to mainstreaming rainwater harvesting in Berlin,” *Geoforum*, vol. 89, no. January, pp. 96–106, 2018.

[4] M. M. Haque, A. Rahman, and B. Samali, “Evaluation of climate change impacts on rainwater harvesting,” *J. Clean. Prod.*, vol. 137, pp. 60–69, 2016.

[5] Y. GDumit Gomez and L. G. Teixeira, “Residential rainwater harvesting: Effects of incentive policies and water consumption over economic feasibility,” *Resour. Conserv. Recycl.*, vol. 127, no. August, pp. 56–67, 2017.

[6] B. Helmreich and H. Horn, “Opportunities in rainwater harvesting,” *Desalination*, 2009.

[7] K. E. Lee, M. Mokhtar, M. Mohd Hanafiah, A. Abdul Halim, and J. Badusah, “Rainwater harvesting as an alternative water resource in Malaysia: Potential, policies and development,” *J. Clean. Prod.*, 2016.

[8] N. H. M. Lani, Z. Yusop, and A. Syafiuddin, “A review of rainwater harvesting in Malaysia: Prospects and challenges,” *Water (Switzerland)*. 2018.

[9] C. Staddon, J. Rogers, C. Warriner, S. Ward, and W. Powell, “Why doesn’t every family practice rainwater harvesting? Factors that affect the decision to adopt rainwater harvesting as a household water security strategy in central Uganda,” *Water Int.*, vol. 43, no. 8, pp. 1114–1135, 2018.

[10] O. O. Aladenola and O. B. Adeboye, “Assessing the potential for rainwater harvesting,” *Water Resour. Manag.*, vol. 24, no. 10, pp. 2129–2137, 2010.