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RAINWATER HARVESTING APPROACH AT DAFFODIL INTERNATIONAL UNIVERSITY (DIU) CAMPUS

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ABSTRACT

Dhaka city faces significant challenges related to water scarcity and urban waterlogging, driven by rapid urbanization, overpopulation, and inadequate water management systems. This study explores the feasibility and implementation of Rainwater Harvesting (RWH) systems as a sustainable solution to mitigate these issues. Using Daffodil Tower as a case study, the analysis focused on hydrological data, building design trends, and optimal tank dimensions and locations for storage and recharge. Results indicate that RWH can provide a reliable supplementary water source, with annual rooftop runoff estimated at 2211.3 m³, supporting up to 16 days of water demand under the Rationing Method (RM). A tank with a capacity of 9942.1 m³ was proposed, designed to integrate seamlessly into the campus environment. Additionally, the study highlighted the importance of recharge structures and logical water distribution methods to maximize system efficiency. These findings confirm the economic and environmental feasibility of incorporating RWH systems in urban settings like Dhaka, offering a sustainable pathway to address the city's pressing water challenges.

1 Introduction

Bangladesh, located between 20°34' to 26°38' North Latitude and between 88° 01' to 92° 41' east longitude is a tropical country. Geographically it is on the extensive floodplains of the Ganges and Brahmaputra river systems (Bangladesh National Portal, 2017). Moreover, during monsoon (June-August) the country receives 1100mm-3400mm rainfall (Bangladesh National Portal, 2017); therefore flooding is a regular natural phenomenon. But the regular natural phenomenon is challenging for the densely populated Bangladesh. According to 2015 census its 158.9 million people live only over the area of 1, 47,570 sq. km (BBS, 2015). Dhaka is the capital of Bangladesh. It is located in central Bangladesh on the lower reaches of the Ganges

Delta. Two major rivers, the Brahmaputra and the Meghan have surrounded the city with its distributaries. The expansion of Dhaka city was mainly around the river Buriganga. The history of the Dhaka city traces back 400 years. At the Beginning of the 16th century, the Mughals established Dhaka city which was 10 sq. km in size (Islam, 2005). Under British rule it grew to 22 sq. km and during the Pakistan period it became 50 sq. km (DWASA, 2011). Since 1953, Dhaka city development was guided by the Town Improvement Act, 1953. In 1959, first master plan was developed, projecting the city area to 320 Sq. km containing 0.575 million people (DWASA, 2011). After independence of Bangladesh in 1971, migration of people from rural and other urban areas to Dhaka City was very high. Due to capital centric development in Bangladesh since independence, 1959 master plan failed to meet the demand and felt the need for another master plan. Therefore another master plan was developed in 1996 estimating an area of 590 Sq. km and 10 million people (DWASA, 2011). But according to 2015 census population of Dhaka City is 15.80 million and it is projected population to be 22 million by 2025 (DWASA, 2015; Uddin et al, 2016). That is, Dhaka is growing at an erratic pace. Dhaka is now the 7th largest city in the World and by 2020 it will be the 2nd largest city in the World (Uddin et al, 2016). In 2011, its urbanization rate was 77.36% (BBS, 2011). With the high speed of urbanization and overpopulation, the city grew in an unplanned manner and became polluted as well as ecologically imbalanced. Because, it imposed vast water demand (DWASA, 2011) and produces a lot of wastewater. Untreated wastewater pollutes both surface and groundwater water sources (Kavarana and Sengupta, 2013). Over the years, water crisis has become a severe problem of Dhaka city and the crisis is twofold. One is acute water shortage during summer with ground water depletion and the other is, urban flooding in monsoon due to waterlogging.

1.1 Rainwater Harvesting Systems And Its Features

Rainwater Harvesting (RWH) is a simple technique of catching and holding rainwater where its falls. Either, we can store it in tanks or we can use it to recharge groundwater depending upon the situation.

Figure 1: Evolution of Air Quality Management

Source: rainwaterharvesting.org (2022)

1.2 Components Of Rainwater Harvesting System

A rainwater harvesting system comprises of components for - transporting rainwater through pipes or drains, filtration, and tanks for storage of harvested water. The common components of a rainwater harvesting system are:-

1.2.1 Catchments

The surface which directly receives the rainfall and provides water to the system is called catchment area. It can be a paved area like a terrace or courtyard of a building, or an unpaved area like a lawn or open ground. A roof made of reinforced cement concrete (RCC), and

JOURNAL OF SCIENCE AND ENGINEERING RESEARCH
Doi: 10.70008/jeser.v1i01.54

galvanized or corrugated sheets can also be used for water harvesting.

1.2.2 Coarse Mesh

It prevents the passage of debris, provided in the roof.

1.2.3 Gutters

Channels that surround the edge of a sloping roof to collect and transport rainwater to the storage tank. Gutters can be semi-circular or rectangular and mostly made locally from plain galvanized iron sheet. Gutters need to be supported so they do not sag or fall off when loaded with water. The way in which gutters are fixed mainly depends on the construction of the house, mostly iron or timber brackets are fixed into the walls.

1.2.4 Storage Facility

There are various options available for the construction of these tanks with respect to the shape, size, material of construction and position of the tank and they are:-

1.2.5 Shape

Cylindrical, square and rectangular.

1.3 Material Of Construction

Reinforced cement concrete (RCC), masonry, ferrocement etc.

1.3.1 Position of Tank

Depending on land space availability these tanks could be constructed above ground, partly underground or fully underground. Some maintenance measures like disinfection and cleaning are required to ensure the quality of water stored in the container. If harvested water is decided to recharge the underground aquifer/reservoir, then some of the structures mentioned below are used.

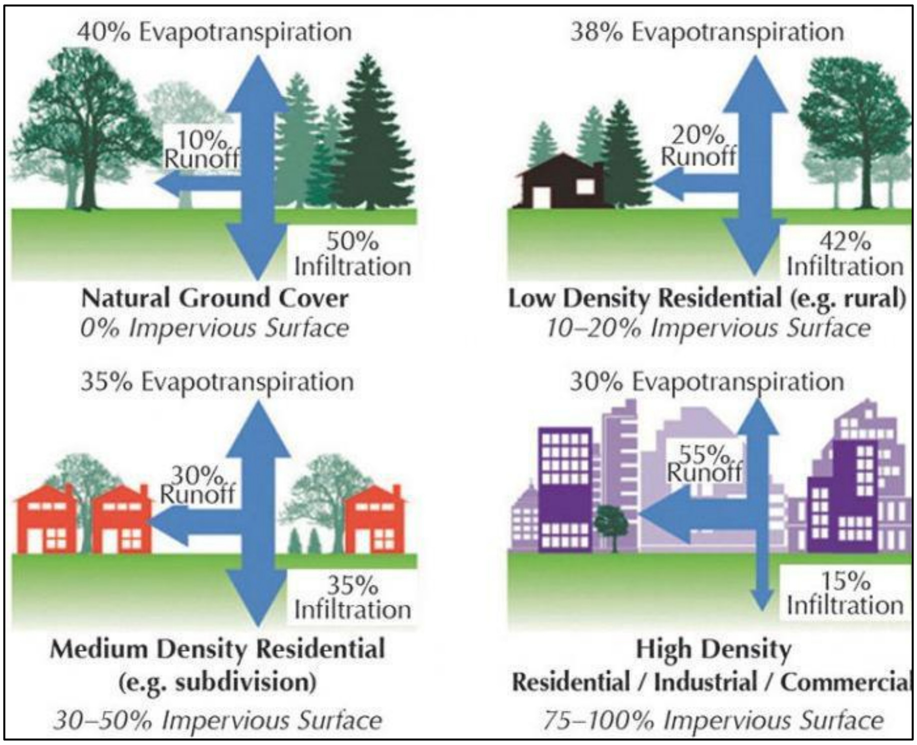
1.3.2 Recharge Structures

Rainwater Harvested can also be used for charging the groundwater aquifers through suitable structures like dug wells, bore wells, recharge trenches and recharge pits. Various recharge structures are possible -some which promote the percolation of water through soil strata at shallower depth (e.g., recharge trenches, permeable pavements) whereas others conduct water to greater depths from where it joins the groundwater (e.g., recharge wells).

1.4 Waterlogging Problem

While in one season there is discriminating water shortage, in the other season cities are increasingly drowning under flood waters of monsoon rain. Dhaka is currently threatened by almost annual basis flooding (GAR summary, 2015; Revealing Risk, Redefining Development, 2015) that is exaggerated in magnitude and frequency by urbanization and human habitation on the flood plain (Flood Response Preparedness Plan, 2014). Urbanization interrupts the natural drainage

Figure 2:Effect of imperviousness on runoff and infiltration (Pipkin, 2015)

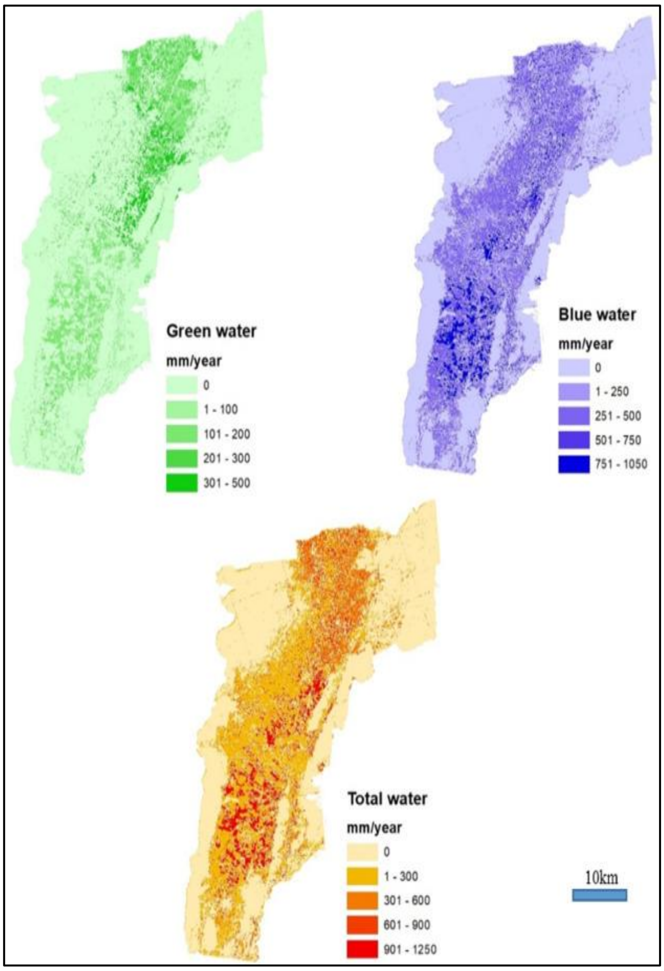


JOURNAL OF SCIENCE AND ENGINEERING RESEARCH
Vol. 01, No. 01, November, 2024, **Page**: 74-88

process and destroys natural watercourses. Moreover, escalating construction of impervious surfaces limits the ability for rainwater to infiltrate into the ground. Impervious surfaces obstruct natural runoff maintenance by plants and soils and amplify surface runoff. The effect of imperviousness on runoff and infiltration has been shown in Figure 2. The figure shows that, natural ground cover with no impervious surface let 50% of the rainwater to infiltrate into the ground, 40% to evapotranspiration from plants and only 10% becomes surface runoff. But with the growing development (roads, buildings, and hard surfaces) the impervious surface increases up to 75-100% in a dense urban area like Dhaka City. In such situations, only 15% of rainwater can infiltrate, 30% goes for evaporate-transpiration and, the remaining 55% water flows as surface runoff. This increased runoff causes sudden flash floods in urban areas. And runoff becomes polluted as solid waste, silt and contaminants are washed off roads, leading to water logging and creating adverse social, physical, economic as well as environmental impacts (Uddin et al, 2016).

In the last decade, a number of flooding incidences occurred in Dhaka city. Particularly devastating flood years include the recent flooding of 2017, 2015 and 2010 along with flooding of 2007 and 2004. In September 11th to 16th, 2004 the heaviest ever rainfall (341 mm) occurred in Dhaka City and its devastating impact paralyzed the city life (Tawhid, 2004). In the flooding of 2004 and 2007, 40% of the city was inundated (Thiele-Eich et al, 2015), and recently it is observed that many areas of Dhaka remain inundated for up to about three days, with only 12 hours of rain (Thiele-Eich et al, 2015; Ahmed, 2012). Recurrence of four most destructive floods within the past 25 years, gives an overview of increasing extreme events (Mirza, 2011). Water scarcity alleviation through water footprint reduction in agriculture:

Figure 3: The effect of soil mulching and drip irrigation



Source: Nouri et al. (2019)

Doi: 10.70008/jeser.v1i01.54

Figure 4: About 450 million people in 31 countries (shaded) face a serious water shortage

In troubled waters

Bleak future

2 LITERATURE REVIEW

Today, only 2.5 per cent of the entire worlds water is fresh, which is fit for human consumption, agriculture and industry. In several parts of the world, however, water is being used at a much faster rate than can be refilled by rainfall. In 2025, the per capita water availability in Bangladesh will be reduced to 1500 cubic meters from 5000 in 1950 (https://www.ijert.org/rainwater-harvesting-and-ground-water-recharging-in-gcoeara-campus). The United Nations warns that this shortage of freshwater could be the most serious obstacle to producing enough food for a growing world population, reducing poverty and protecting the environment. Hence the water scarcity is going to be a critical problem if it is not treated now in its peanut stage. Contrasting figures of water scarcity in world between two timelines (1999 & 2025) are shown in the fig. 4 & fig 5. Some of the major city where rainwater harvesting has already implemented is Dhaka (Centre for Science and Environment's (CSE) designs sixteen model projects in Dhaka to setup rainwater harvesting structures in different colonies and institutions), Bangladesh and Indore (Indore Municipal Corporation (IMC) has announced a rebate of 6 per cent on property tax for those who have implemented the rainwater harvesting work in their house/bungalow/building), India.

Rainwater Harvesting is a long traditional practice of southern part of rural Bangladesh. Usually people collect rainwater from the roof via gutter, or from open sky, with stretched plastic sheet (Figure 6). Collected rainwater is stored in traditional earth pot/vessel (Figure 6). But, traditional wisdom has been ignored, the in urban context of Bangladesh.

It is only recently that the growing problem of water shortage and water logging has lead urban dwellers of Dhaka City to think of RWH. However, several research, studies and projects have been carried out by researchers, academicians and different institutions. Numerous theoretical studies have been conducted to analyze the feasibility of RWH in Dhaka city, and those studies have proved to be not only feasible, but also economic (Dakua and Metal, 2013; Rahman and Hasan, 2016; Yasmin and Rahman, 2013). Study has shown that, rainwater harvesting for domestic consumption in urban areas of Bangladesh might be economic (Choudhury and Sultana, 2010). It has also been identified that, excess water is available during the month of October, and maximum deficit occurs during April. So excess water obtained during rainy season can be stored properly for use in the dry period (Sikder, 2013). Results show that, 33% water demand can be met through RWH, with individual harvesting system, and 10% water demand can be met with community based RWH system. These analyses suggest that, in Dhaka, RWH system can be used in conjunction with conventional water supply system to improve the present water scarcity (Rahman et al, 2011; Sikder, 2013). Research has analyzed that, the supply of rainwater is 293% (almost three times) against its demand in flushing Water Closets (WC) on a six-storied residential building (Zaman et al, 2017). Again, some field projects have been conducted. For example, ITN-BUET and Water Aid Bangladesh (WAB) has demonstrated Rainwater Harvesting Systems at four sites . Another project was carried out by DWASA and IWM in Segunbagicha and in Lalmatia DWASA premises. The research revealed that, Rainwater in Dhaka city has good quality standard for using in

Figure 5: Traditional rainwater collection and storage process

Source: Rahman (2017)

artificial recharge to aquifer layers. But proper operation and maintenance is prerequisite to ensure standard water quality (IWM, 2011).

Figure 6: RWH project of Water Aid and ITN BUET

3 METHOD

Table 1: Monthly Rainfall Data Of Dhaka Station

Month	Rainfall (mm)
January	7.7
February	28.9
March	65.8
April	156.3
May	339.4
June	340.4
July	373.1
August	316.5
September	300.4
October	172.3
November	34.4
December	12.8
TOTAL	**2148.8**

Source: http://www.bmd.gov.bd/p/Rainfall-Deviation-Map

DIU is located at 90º22º35ºE longitude and 23º45º19ºN latitude in Dhaka district at an elevation of about 306.38 square *kilometers* above mean sea level. DIU as a tropical climate and receives high rainfall during Southwest monsoon (June-September) and retreating Northeast monsoon (December-January). Average annual rainfall ranges between170-180 cm.

3.1 Hydrological Analysis

On the basis of experimental evidence, Mr.H.Darcy, a French scientist enunciated in 1865, a law governing the rate of flow (i.e., the discharge) through the soils. According to him, this discharge was directly proportional to head loss (H) and the area of cross-section (A) of the soil, and inversely proportional to the length of the soil sample (L).

Water Harvesting Potential or Volume of Water Received (m^3):

$$Volume = Area\ of\ Catchment\ (m^2) \times Rainfall\ (mm) \times Runoff\ Coefficient$$

JOURNAL OF SCIENCE AND ENGINEERING RESEARCH
Vol. 01, No. 01, November, 2024, **Page**: 74-88

Similarly, based on the above principle, water harvesting potential of the catchment area was calculated.

Where:

- Area of Catchment (m²) is the surface area where rainwater is collected.
- Rainfall (mm) is the amount of rainfall in millimeters.
- Runoff Coefficient represents the proportion of rainwater that can be effectively harvested (depending on the surface type).

Methods For Storage Of Harvested Rainwater In Tank

Finally, we need to store the water which is obtained from the rooftop areas of the different buildings. The volume of tank which stores the harvested water will be directly proportional to the total volume of water harvested. Technically, there are two types of methods for distributing the harvested rainwater:-

- Rationing Method (Rm)
- Rapid Depletion Method (Rdm)

4 FINDINGS

Just to start with, now let us consider only one Daffodil Tower and proceed with calculation in details.

The total rooftop area of the Daffodil Tower available for the rainwater harvesting is 1053m^2. The cumulative runoff that can be captured from the paved area is calculated using Bangladesh Meteorological Department.

4.1 Computation of Volume of Runoff Per Year

Total roof area of Daffodil Tower was calculated = 1053 m^2

Average annual rainfall at Daffodil Tower =2100mm/year = 2.1 m^3/year

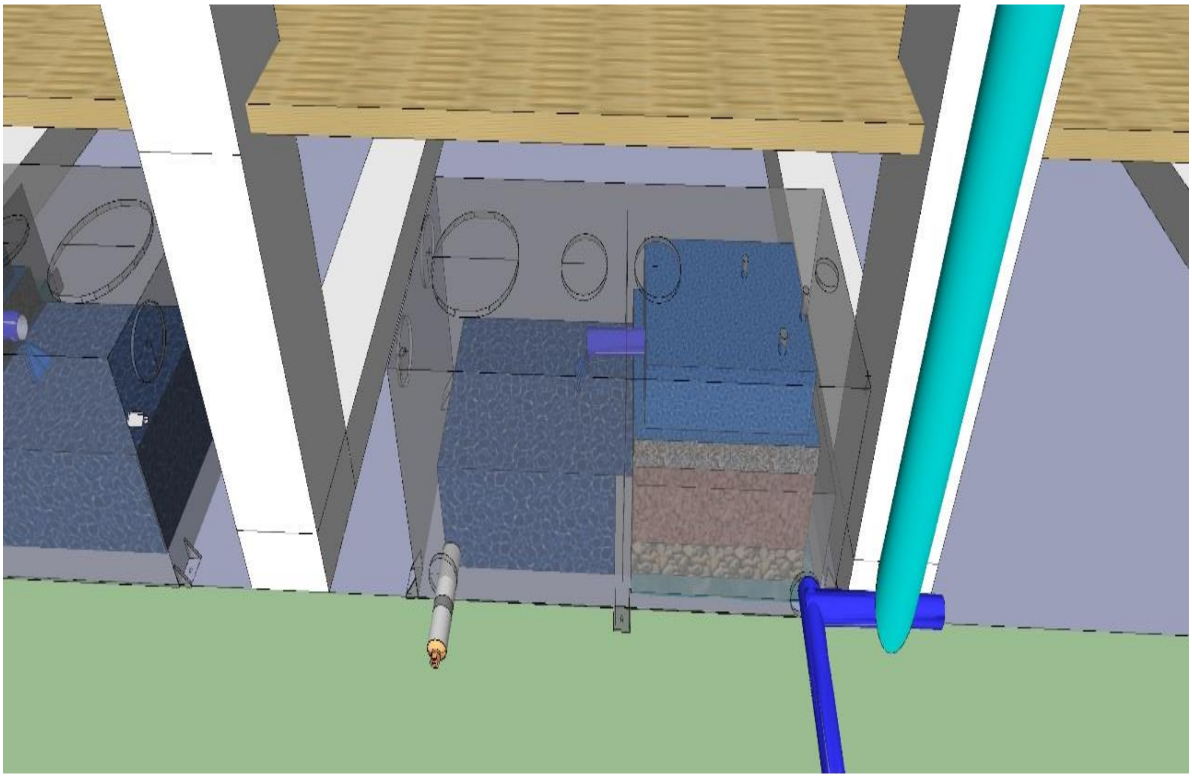
Total volume of surface runoff water supposed to be collected=1053x 2.1= 2211.3 m^3/year

Figure 7: Daffodil Tower model

Doi: 10.70008/jeser.v1i01.54

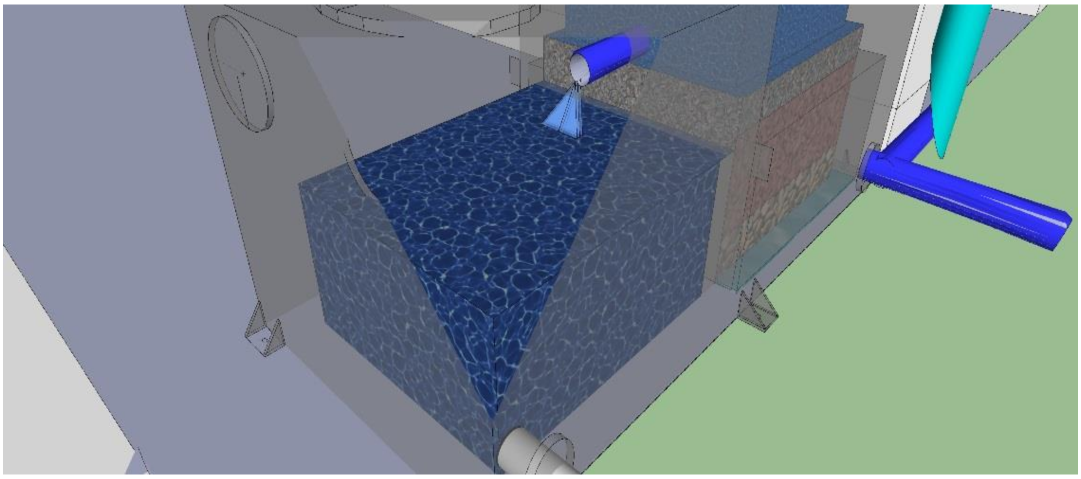
Figure 8: Daffodil Tower Roof Top

Figure 9: Daffodil Tower Roof Top



JOURNAL OF SCIENCE AND ENGINEERING RESEARCH
Vol. 01, No. 01, November, 2024, **Page**: 74-88

Figure 10: Daffodil Tower Sand bed Filter Model



Given below the table no 4 which gives the monthly rainfall and discharge runoff obtained from the rooftop area of Daffodil Tower and the corresponding graph are also plotted in the fig.14 and fig.15.

Table 2: Showing Rainfall & Discharge of Daffodil Tower Campus

Sl. No	Month	Rainfall(mm)	Discharge(m^3)
1	January	7.7	8.1
2	February	28.9	30.4
3	March	65.8	69.3
4	April	156.3	164.6
5	May	339.4	357.4
6	June	340.4	358.4
7	July	373.1	392.9
8	August	316.5	333.3
9	September	300.4	316.3
10	October	172.3	181.4
11	November	34.4	36.2
12	December	12.8	13.5
	TOTAL	**2148.8**	**2261.8**

Source: http://www.bmd.gov.bd/p/Rainfall-Deviation-Map

4.2 Rationing Method (RM)

Assuming a per capita water demand of 70 liters per day (equivalent to 0.07 m³/day) and a total of 2,000 students at Daffodil Tower, the daily water consumption is calculated as 2000×0.07=140 m³/day. Utilizing preserved water, the number of days the stored water can meet demand is determined by dividing the total volume of stored water by the daily demand. For Daffodil Tower, with an estimated water storage capacity of 2211.3 m³, the water supply would last approximately 2211.3÷140=15.8 days, which is rounded up to 16 days. To ensure the long-term storage of water in good condition, appropriate preservation chemicals should be

Assuming a per capita water demand of 100 liters per day (equivalent to 0.1 m³/day) and a total of 2,000 consumers, the daily water consumption is calculated as 2000×0.1=200 m³/day. The number of days the preserved water can be utilized is determined by dividing the total stored water by the daily demand. For a stored water volume of 2211.3 m³, the supply would last approximately 2211.3÷200=11.06 days, which is rounded to 11 days. In comparison, the Rationing Method (RM) allows the preserved water to be utilized for 16 days, whereas the Rapid Depletion Method (RDM) limits utilization to approximately 11 days due to higher per capita water demand.

JOURNAL OF SCIENCE AND ENGINEERING RESEARCH
Vol. 01, No. 01, November, 2024, **Page**: 38-55

Figure 11: Showing Amount of Rainfall collected in throughout the year

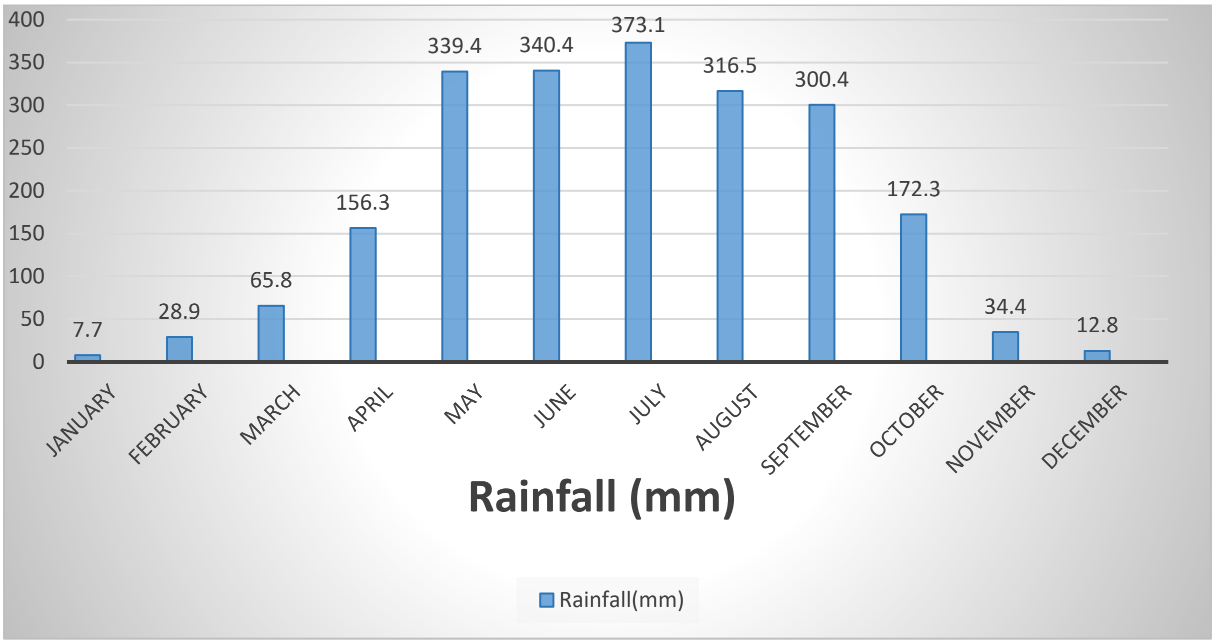


Figure 12: Showing Volume of water Collected from Rainfall throughout the year

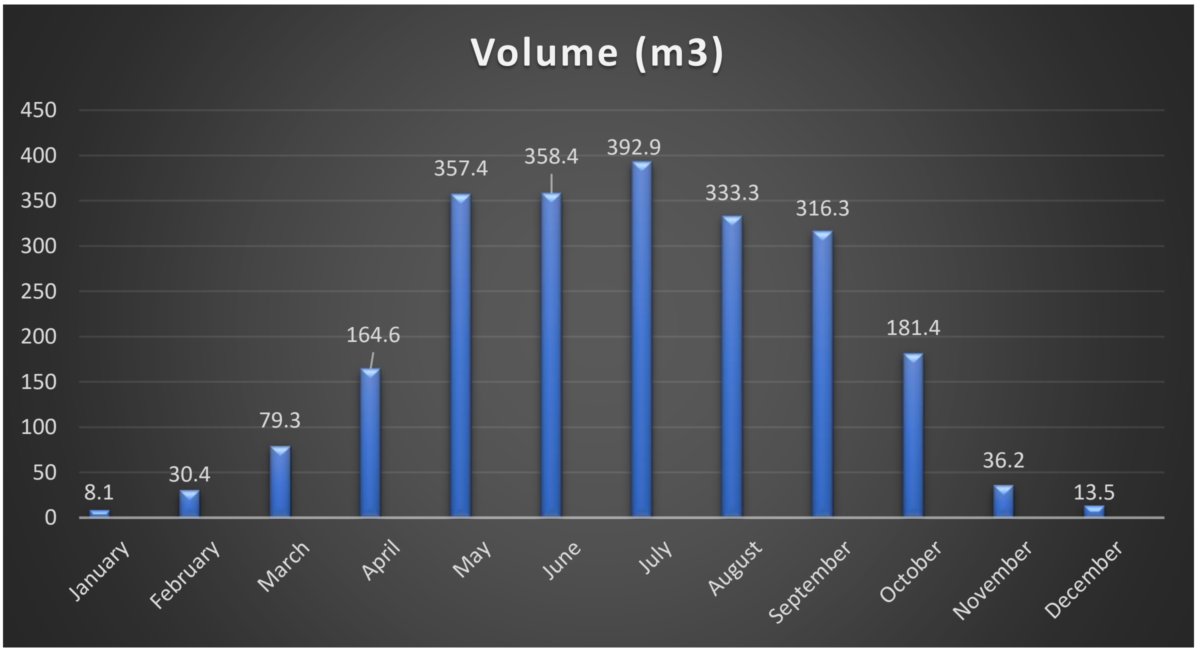


Table 3: Analysis of distribution of stored harvested water by two methods

Sl no.	Building Name	Rooftop area(m^2)	Reservoir Capacity (R)	RM = R/30 (days)	RDM= R/45 (days)
1	daffodil tower	1053	15593.2(R1)	519.8	346.5

JOURNAL OF SCIENCE AND ENGINEERING RESEARCH
Vol. 01, No. 01, November, 2024, **Page**: 74-88

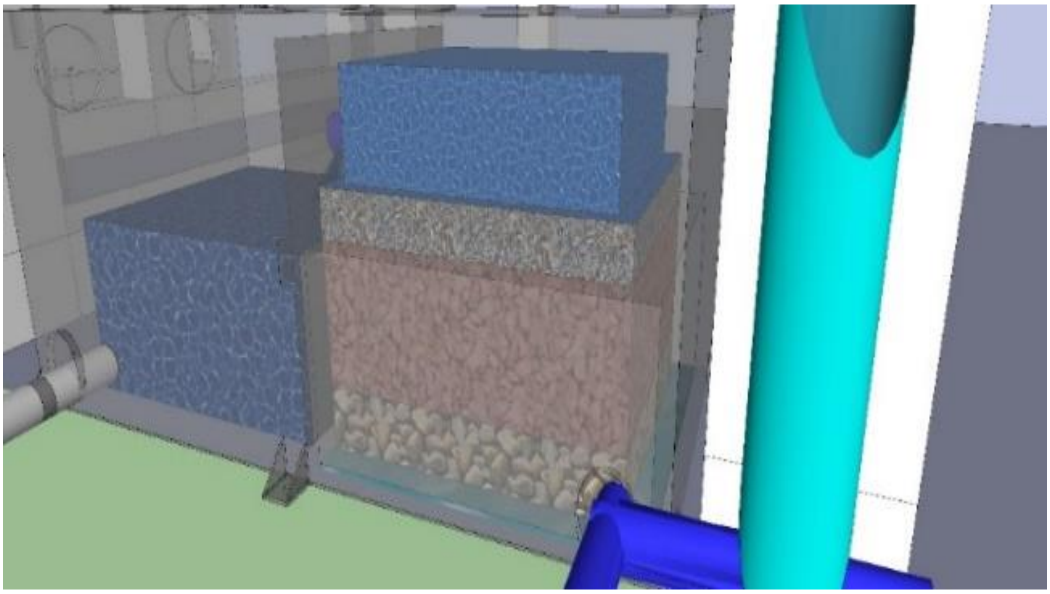
4.3 Optimum Dimension of the Tank

For Daffodil Tower, the total water collected in July is estimated to be 390 m^3, which determines the required tank size. Assuming a tank height of 3 meters, the base area is calculated as 390÷3=130 m^2. Considering land availability, a rectangular base with dimensions of 13 meters by 10 meters and a height of 3 meters is selected, making the rectangular tank the optimal choice for storage.

4.4 Filtration

Rainwater collected on the roof is very pure and clean. However, there are many substances, which get mixed up with this pure water on the roof (leaves, bird droppings, dust etc.). These contaminants need to be filtered before the rainwater is stored.

Figure 13: Sand bed filter (i)

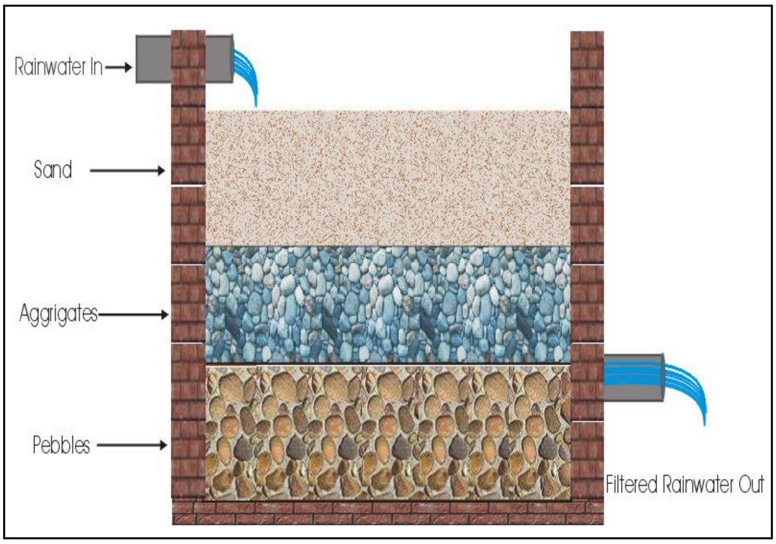


4.5 Sand bed filter

Sand bed filter is the traditional method where coarse riverbed sand, pebbles and aggregates are filled as layers one above the other in a confined masonry structure.

Rainwater is allowed at the top from one end and filtered water is drawn from the other side.

Figure 14: Sand bed filter (ii)



JOURNAL OF SCIENCE AND ENGINEERING RESEARCH
Doi: 10.70008/jeser.v1i01.54

5 DISCUSSION

The findings from this study demonstrate the significant potential of rainwater harvesting (RWH) as a sustainable solution to Dhaka's growing water scarcity challenges. The results show that for Daffodil Tower, a total of 2211.3 m³ of rainwater can be harvested annually, with monthly runoff varying depending on rainfall patterns. Using the Rationing Method (RM), this volume could sustain 2000 individuals for up to 16 days, while the Rapid Depletion Method (RDM) would limit usage to 11 days due to higher per capita demand. These findings align with earlier studies by Rahman and Hasan (2016), who emphasized the economic and practical feasibility of RWH systems in urban Bangladesh. Moreover, the results reinforce the conclusions of Sikder (2013), who identified that approximately 33% of water demand in Dhaka could be met through individual RWH systems. This study thus supports the growing body of evidence that RWH can effectively supplement traditional water supply systems in urban contexts.

Comparing these findings with previous research highlights both consistencies and variations. For instance, the study by Yasmin and Rahman (2013) estimated that community-based RWH systems could meet up to 10% of Dhaka's water demand, a lower percentage than the 33% reported for individual systems by Sikder (2013). This study's results align more closely with individual system estimates, underscoring the importance of rooftop RWH in densely populated urban areas. Additionally, this study highlights the advantage of integrating RWH with existing water supply infrastructure, as suggested by Rahman et al. (2011). The ability to collect 2261.8 m³ of rainwater annually from a single building like Daffodil Tower demonstrates the scalability of such systems when implemented across multiple buildings.

However, the findings also reveal critical challenges associated with RWH. The storage capacity of 2211.3 m³ at Daffodil Tower, while substantial, falls short of addressing long-term water needs for its population. As urbanization intensifies, the increased impervious surfaces further limit natural groundwater recharge, exacerbating water scarcity issues. This aligns with findings by Kavarana and Sengupta (2013), who noted that untreated wastewater and urban runoff contribute significantly to groundwater pollution in Dhaka. These challenges necessitate the integration of RWH with groundwater recharge systems, as suggested by Zaman et al. (2017), to enhance the long-term sustainability of water resources in the city.

The findings also underline the importance of proper filtration and maintenance for RWH systems. This study utilized sand bed filters to purify rainwater, echoing the recommendations of Choudhury and Sultana (2010) for ensuring water quality in RWH projects. Moreover, the research revealed that seasonal variations in rainfall significantly impact water availability, with a surplus during monsoon months and deficits during the dry season. Previous studies by ITN-BUET and WaterAid Bangladesh (2011) emphasized the need for efficient storage and distribution mechanisms to manage such seasonal disparities. These findings support the argument for adopting adaptive RWH systems capable of mitigating the impacts of seasonal variability on water supply.

6 CONCLUSION

Considering the pressing challenges of water scarcity and waterlogging in Dhaka city, rainwater harvesting (RWH) emerges as a practical and sustainable solution to mitigate these issues. This study evaluated the feasibility and suitability of implementing RWH systems, specifically focusing on Daffodil Tower as a case study. The analysis demonstrated that integrating RWH into current building development trends is both viable and essential. Through hydrological analysis and 3D modeling, the optimal dimensions and locations for storage tanks and recharge structures were identified, highlighting the practicality of underground reservoirs due to their cost-effectiveness and efficient utilization of space. The study also emphasized the importance of logical water distribution methods, such as the Rationing Method (RM) and Rapid Depletion Method (RDM), for maximizing the usability of stored rainwater. By proposing an RCC underground tank with a storage capacity of 9942.1 m³, the study illustrated a tangible solution for addressing water demand on the Daffodil International University (DIU) campus. This research confirms that RWH, when thoughtfully integrated into urban planning and architectural design, can play a pivotal role in alleviating water scarcity, enhancing urban water management, and promoting sustainable development in Dhaka city.

References

Ahmed, Z. N. (2012). *Dhaka floods: The need to act now; Agenda for urban concern 2000-2005* (pp. 296-299). The Daily Star and Bangladesh Scouts.

Bangladesh Bureau of Statistics. (2016). *Report on Bangladesh sample vital statistics 2015*. Statistics and Informatics Division (SID), Ministry of Planning, Government of the People's Republic of Bangladesh. Retrieved from www.bbs.gov.bd

Bangladesh Meteorological Department. (n.d.). *Rainfall deviation map*. Retrieved from http://www.bmd.gov.bd/p/Rainfall-Deviation-Map

Bangladesh National Portal. (2017). *Ministry of Information, GoB*. Retrieved from http://www.bangladesh.gov.bd/site/page/812d94a8-0376-4579-a8f1-a1f66fa5df5d/

Choudhury, I., & Sultana, F. (2010). Rainwater harvesting for domestic consumption in Bangladesh: Sizing and construction of storage cisterns. *American Society for Engineering Education*, 15(1011), 1–10.

Dhaka Water Supply and Sewerage Authority. (2011). *Monthly Information Report (MIR).*

Dhaka Water Supply and Sewerage Authority. (2015). *Annual report 2014-2015*. Dhaka.

Dakua, M., Akhter, F., Biswas, P. P., Siddique, L. R., & Shihab, R. M. (2013). Potential of rainwater harvesting in buildings to reduce over-extraction of groundwater in urban areas of Bangladesh. *European Scientific Journal*, 3(Special Edition), 1–10.

Flood Response Preparedness Plan of Bangladesh. (2014). Department of Disaster Management, Ministry of Disaster Management and Relief, Government of Bangladesh.

Islam, N. (2005). *Dhaka now: Contemporary urban development*. Bangladesh Geographical Society (BGS), Department of Geography, Dhaka University.

Islam, M. R., Zamil, M. Z. H., Rayed, M. E., Kabir, M. M., Mridha, M. F., Nishimura, S., & Shin, J. (2024). Deep Learning and Computer Vision Techniques for Enhanced Quality Control in Manufacturing Processes. *IEEE Access, 12*, 121449-121479. https://doi.org/10.1109/ACCESS.2024.3453664

Kavarana, G., & Sengupta, S. (2013). *Catch water where it falls: Toolkit on rainwater harvesting*. Center for Science and Environment, India.

Khalequzzaman, M. D. (1994). Recent floods in Bangladesh: Possible causes and solutions. *Natural Hazards*, *9*(1), 65–80.

Mazumder, M. S. A., Rahman, M. A., & Chakraborty, D. (2024). Patient Care and Financial Integrity In Healthcare Billing Through Advanced Fraud Detection Systems. *Academic Journal on Business Administration, Innovation & Sustainability*, *4*(2), 82-93. https://doi.org/10.69593/ajbais.v4i2.74

Md Samiul Alam, M. (2024). The Transformative Impact of Big Data in Healthcare: Improving Outcomes, Safety, and Efficiencies. *Global Mainstream Journal of Business, Economics, Development & Project Management*, *3*(03), 01-12. https://doi.org/10.62304/jbedpm.v3i03.82

Mirza, M. M. (2011). Climate change, flooding in South Asia, and implications. *Regional Environmental Change*, *11*(1), 95–107.

Mosleuzzaman , M., Hussain, M. D., Shamsuzzaman, H. M., Mia, A., & Hossain, M. D. S. (2024). Electric Vehicle Powertrain Design: Innovations In Electrical Engineering. *Academic Journal on Innovation, Engineering & Emerging Technology*, *1*(01), 1-18. https://doi.org/10.69593/ajieet.v1i01.114

Mosleuzzaman, M., Shamsuzzaman, H. M., & Hussain, M. D. (2024). Engineering Challenges and Solutions in Smart Grid Integration with Electric Vehicles. *Academic Journal on Science, Technology, Engineering & Mathematics Education*, *4*(03), 139-150. https://doi.org/10.69593/ajsteme.v4i03.102

Mosleuzzaman, M. D., Hussain, M. D., Shamsuzzaman, H. M., & Mia, A. (2024). Wireless Charging Technology for Electric Vehicles: Current Trends and Engineering Challenges. *Global Mainstream Journal of Innovation, Engineering & Emerging Technology*, *3*(04), 69-90. https://doi.org/10.62304/jieet.v3i04.205

Nandi, A., Emon, M. M. H., Azad, M. A., Shamsuzzaman, H. M., & Md Mahfuzur Rahman, E. (2024). Developing An Extruder Machine Operating System Through PLC Programming with HMI Design to Enhance Machine Output And Overall Equipment Effectiveness (OEE). *International Journal of Science and Engineering*, *1*(03), 1-13. https://doi.org/10.62304/ijse.v1i3.157

Patro, G. K. (2019). *A flood mitigation strategy for floodplain areas in India* (Doctoral dissertation). Retrieved from http://etd.nitrkl.ac.in

Revealing Risk, Redefining Development. (2015). Retrieved from http://www.preventionweb.net/english/hyogo/gar/2011/en/home/index.html

Rainwaterharvesting.org. (n.d.). *Crisis scarcity*. Retrieved from http://www.rainwaterharvesting.org/Crisis/Crisis_Scarcity.htm

Sikder, M. (2013). Potential of rainwater harvesting in Dhaka city. *ResearchGate*. Retrieved from https://www.researchgate.net/publication/257934572_Potential_of_Rainwater_harvesting_in_Dhaka_city

Sultana, F. (2007). Sustainable water supply: Rainwater harvesting for multistoried residential apartments in Dhaka, Bangladesh (Master's thesis). Texas A&M University. Retrieved from https://www.researchgate.net/publication/41014760_Sustainable_water_supply_rainwater_harvesting_for_multistoried_residential_apartments_in_dhaka_bangladesh

Sharma, R. K. (2010). Rainwater harvesting at N.I.T Rourkela. *Department of Civil Engineering, National Institute of Technology, Rourkela, India*. Retrieved from http://ethesis.nitrkl.ac.in

Shamim, M. (2022). The Digital Leadership on Project Management in the Emerging Digital Era. *Global Mainstream Journal of Business, Economics, Development & Project Management*, *1*(1), 1-14.

Shamsuzzaman, H. M., Mosleuzzaman, M. D., Mia, A., & Nandi, A. (2024). Cybersecurity Risk Mitigation in Industrial Control Systems Analyzing Physical Hybrid And Virtual Test Bed Applications. *Academic Journal on Artificial Intelligence, Machine Learning, Data Science and Management Information Systems*, *1*(01), 19-39. https://doi.org/10.69593/ajaimldsmis.v1i01.123

Shofiullah, S., Shamim, C. M. A. H., Islam, M. M., & Sumi, S. S. (2024). Comparative Analysis of Cost and Benefits Between Renewable And Non-Renewable Energy Projects: Capitalizing Engineering Management For Strategic Optimization. *Academic Journal on Science, Technology, Engineering & Mathematics Education*, *4*(03), 103-112. https://doi.org/10.69593/ajsteme.v4i03.100

Thiele-Eich, I., Burkart, K., & Simmer, C. (2015). Trends in water level and flooding in Dhaka, Bangladesh and their impact on mortality. *International Journal of Environmental Research and Public Health*, *12*(1), 1196–1215.

Tawhid, K. G. (2004). Causes and effects of water logging in Dhaka city, Bangladesh. *TRITA-LWR* (Unpublished Master's thesis). Royal Institute of Technology, Stockholm. Retrieved from http://www2.lwr.kth.se/Publikationer/PDFFiles/LWREX0445

Uddin, S., Alam, M. A., & Parvej, M. (2016). Artificial infiltration of roof rainwater in Dhaka city. *International Journal of Engineering Technology, Management and Applied Sciences*, *4*(11), 1–10. Retrieved from http://www.ijetmas.com

Zaman, A., Ahsan, T., & Bashneen, S. (2011). Opportunities and utilization of rainwater harvesting in residences of Dhaka city. *Academia.edu*. Retrieved from http://www.academia.edu/5082583/OPPORTUNITIES_AND_UTILIZATION_OF_RAINWATER_HARVESTING_IN_RESIDENCES_OF_DHAKA_CITY