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Enhancing Water Security in Commercial Buildings through Rainwater Harvesting and Innovative Strategies: A Case Study in Dhaka, Bangladesh.

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INTRODUCTION & AIM

Bangladesh has transitioned from low-income status to a mix of low-middle and lower-middle-income categories (Zafar, Reaz, & Tasin, 2020), with its economy growing steadily since the 1980s, averaging 5%–6% annual GDP growth (Akter Jahan, 2023). The country's expected graduation from the UN's Least Developed Country (LDC) status in 2026 will bring new challenges. Bangladesh has benefited from preferential export access as an LDC, particularly in the RMG sector, a significant consumer of groundwater for garment manufacturing (Atiur Rahman, 2023).

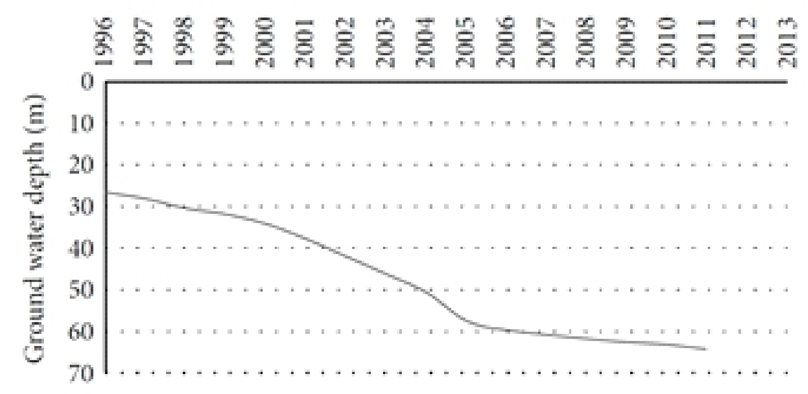
The country's urban population is expanding faster than in other South Asian nations, with employment opportunities drawing rural migrants. Export-led growth has boosted jobs in urban and suburban areas, spurring the construction and transportation sectors and reducing poverty (Hossain, Sen, & Sawada, 2013). However, rapid, often unplanned, urban growth has strained basic resources like safe water access.

Dhaka, Bangladesh's capital, is a megacity with over 400 years of history. Covering 306.4 km², Greater Dhaka now has 23.9 million people, 10.2 million of whom live in the central city (World Population Review, n.d.). This population places enormous pressure on the city's water supply. The Dhaka Water Supply and Sewerage Authority (DWASA), established in 1874, supplies the city with water but struggles to meet demand (Islam et al., 2021).

Bangladesh faces severe climate change challenges. The World Risk Report 2021 ranks Bangladesh 13th among 36 high-risk countries, with a mean risk value of 16.23% (Radtke & Weller, 2021). Coastal communities are most vulnerable, and erratic rainfall and water security are key concerns (Environment, 2017).

DWASA supplies 2,520 million liters of water per day, with 87% from groundwater and 13% from surface water (WASA, 2024). However, groundwater levels are declining by about 3 meters annually, posing a significant threat to meeting future water demand (M. Islam et al., 2021). Dhaka's surrounding rivers—Buriganga, Turag, Sitalakaha, and Balu—are heavily polluted, making surface water treatment costly and difficult (Akram et al., 2024). Over the past decade, DWASA has had to source water from increasingly distant locations, now up to 45 km away, due to river pollution.

Rainwater harvesting presents a potential solution. A pilot project by DWASA and the Institute of Water Modelling (IWM) in 2010-11 found that if 60% of Dhaka's rooftop rainfall were harvested, it could recharge aquifers with 90 billion liters of water annually. This could provide over 200 million liters daily (Ahmed & Nazmunnahar, 2015). Recognizing this potential, RAJUK and the National Building Authority have incorporated rainwater harvesting into building regulations.



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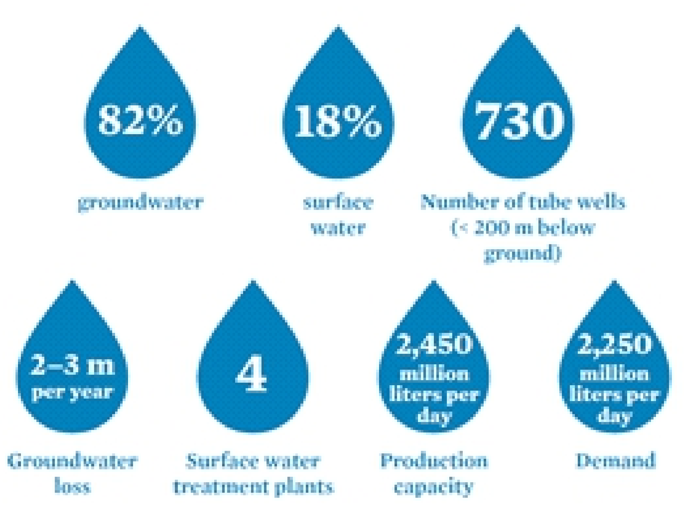

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Water Supply

Item	Unit	2017-2018	2018-2019	2019-2020	2020-2021
Deep Tube well	Nr	795	827	896	906
Water Treatment Plant	Nr	4	4	4	5
Water Production/day	MLD	2,450	2,500	2,560	2,590
Water Line	Km	3,600	3,720	3,850	3,875
Water Connection	Nr	371,766	3,79,686	392,400	393,600
Overhead Tank	Nr	38	38	38	38
Street Hydrant	Nr	1,643	1,643	1,643	1,500

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Figure 1: Groundwater depletion in Dhaka City Source (WASA 2021)

Figure 2: Dhaka -Water Source

Figure 3: Dhaka WASA water supply ataglance (WASA 2021)

METHOD

This study adopts a case study approach, focusing on a commercial high-rise building on Gulshan Avenue, Dhaka, recognized for its exemplary water management and LEED Platinum certification. The methodology incorporates qualitative and quantitative methods to explore how rainwater harvesting and other innovative water strategies enhance water security in commercial buildings.

1. Site Selection and Contextual Overview

The selected building is a 17-story commercial office space on Gulshan Avenue, Dhaka, encompassing 15 Katha (10,800 sqft). Initially, the site housed a residential building leased to a restaurant. Recognizing the commercial potential of the location, the owner converted the property into a high-rise commercial office building. The building is designed with 65% ground coverage with 17 stories, an overall height of 190 feet following an approved plan.

This building is Bangladesh's first LEED-certified commercial new construction, achieving an 80+ point and Platinum certification from the U.S. Green Building Council (USGBC) in 2017.

2. Data Collection Methods

Data were gathered through three primary methods:

On-Site Observations, Interviews with Key Stakeholders, Review of LEED Certification Documentation.

3. Data Analysis

- Qualitative Analysis: Data from on-site observations and stakeholder interviews were thematically analyzed to identify key strategies and best practices contributing to the building's 50% water efficiency. Themes such as technology integration, operational practices, and stakeholder collaboration were explored to understand their roles in enhancing water security.
- Quantitative Analysis: The plumbing engineering design was quantitatively analyzed to benchmark the building's water use efficiency against national and global standards.

4. Validation and Cross-Verification

To ensure the accuracy and reliability of the findings, the results from the interviews and on-site observations were cross-verified with the LEED certification documents. Any discrepancies identified during this process were addressed through.

RESULTS & DISCUSSION

Building water supply system

The main source of water for the building is DWASA, with a deep tube well installed as a backup source. The building is equipped with a dual plumbing system to utilize harvested rainwater. Reverse osmosis is used in the Water Treatment Plant (WTP), and both treated water and harvested rainwater are used for toilets, general washing, and gardening purposes.

Meteorological data for rainwater

The geographical coordinates of Bangladesh are between latitude 20°34' to 26°38' N and longitude 88°01' to 92°41 E. The country has tropical monsoons with high rainfall from April and September The annual rainfall of Dhaka City varies from 1169 to 3028 mm, summing up the average yearly rainfall to 2076 mm. (Meteorological, 2021)

Quality of Rainwater

The quality of rainwater is significantly good in Dhaka and has a large scope of use. The catchment area of the rainwater on the building roof that is built with concrete has a low runoff coefficient, and the stored rainwater requires to be tested periodically to maintain the quality needed for potable use. The rainwater at the building is treated on-site with the RO system located in the second basement.

Rainwater calculation

- Pre-construction run-off: (AxRxC)
  Land area (A) = 1004 square meter
  Yearly Average Rain Fall = 2148mm (2.148 meters)
  Runoff Coefficient –impermeability (C)\ = .2 (AxRxC)
  = 1004 x 2.148 x .2 = 2156.59 Lt
- Post-construction runoff: (according to RAJUK building rule, 50% is the permitted ground coverage.)
  Catchment Area of the building roof = 502 sqm
  Total rainwater collection= From Roof + From Ground Area (mostly earth and percolated green) + Building Premises (mixed surface material & non permeable outdoor space)

A. Roof area: (502 sqm x 2.148 m) x .80 (impermeability)
= 863 Liters

B. Garden area: (251sq.m x 2.148m yearly rainfall x .50 (impermeability) = 270 Lt

C. Premises (251sq.m x 2.148m yearly rainfall x .65 (impermeability) = 350.45 Lt

Total: A+B+C= 863+270+350.45 = 1438.45 Lt

Occupants/ users water consumption calculation:

The calculation is based on low-flow fixtures installed in the Cityscape Tower. Assumptions for normal usage are: females use water closets three times a day, males use closets once and urinals twice, while all users wash hands three times and use sinks once daily. These estimates are lower than the typical 45 liters per person per day used for conventional Sewage Treatment Plant (STP) design in Bangladesh. In green buildings, water demand drops to 20-25 liters per person daily, depending on the fixtures' flow rates.As a result, some variance is expected between LEED and local norms. For STP (75 KLD) design, peak flow is calculated as three times the average, with an hourly flow of 3.75 cubic meters.

Type of Space Use - Commercial Office

Number of People (Regular) – 450 nos.
Number of guests - 150 nos. per day.
Regular Water Consumption-
@45 Lt/per day x 450 = 20,250 Lt/day
@ 20 Lt/per day x 150 = 3,000 Lt/day
Other requirements (as considered in water requirements calculation) = 4,000 Lt/day
Total Water Consumption per day = 27,250 Lt
Considering 10% extra use = 29,975 liters/day.
Available waste water per day = Maximum 70% of regular water consumption = 29,975 x 0.7
= 20,982 liters/day
= 25,000 Lt / day approx

Assuming peak flow is 3 times of normal flow = 3 x 25000 liters/day = 75000 liters/day
i.e. 75 KLD (m3/day) or 75,000 ÷ 20 = 3.75 m3/hr.
We have used 20 hours of daily operation to calculate the hourly average inflow. This 20 hours operation is considered keeping in mind the peak flow situation. Practically standard operation hours are between 8-12 i.e. with normal operation time of 8 hours plus overtime of 4 hours on average, and average daily waste inflow of 3.75 cum. x 8 = 30 cum or 30 KLD

In the primary process, the basis of calculation is as below:

1. Aeration Tank: Retention time required per general standard = 14-16 hours
Proposed volume = 2,000 cubic feet (56 cum.) can handle a waste flow of maximum 3.5 cum/hr.

2. Clarifier Tank: retention time required per general standard = 2 - 2.5 hours
Proposed volume = 250 cubic feet (7 cum.) can handle a maximum of 3.5 cum./hours.

The above calculation shows that the proposed system can provide proper retention time even during peak flow. Typically, from 6.00 am to 11.00 am, the wastewater generation rate is 2.5 times of the averagewee must calculate the STP capacity considering this peak flow. Otherwise, during everyday peak time, outflow quality will abnormally decrease. Moreover, in any continuous process where the retention time requires more than 12 hours for any part of the system, where there is a possibility of regular peak inflow, the system must be designed to support peak flow for 20-24 hours of operation so that it functions well within the standard 8-12 hours operation.

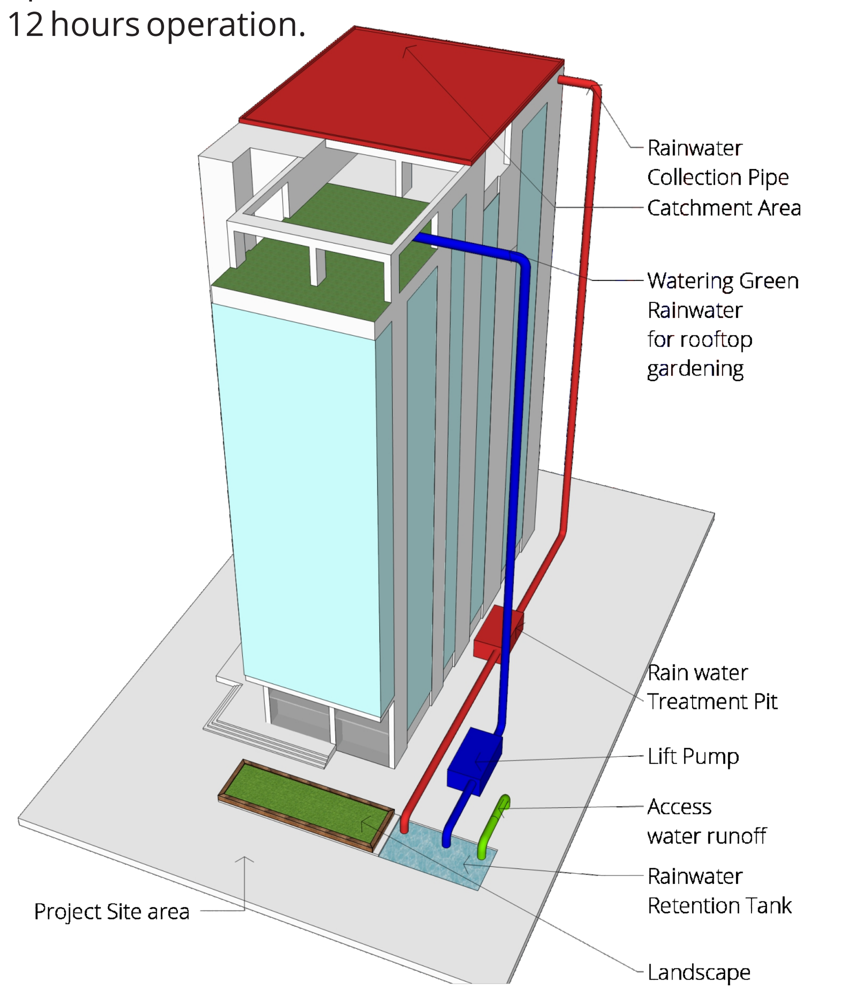

Figure 4: Schematic diagram of rain water harvesting in the studied-building

CONCLUSION

Dhaka, a densely populated megacity, faces escalating challenges in meeting the growing demand for safe water while natural resources continue diminishing. Enhancing water security is essential for the city's long-term sustainability, aligning with the United Nations' Sustainable Development Goal 6 (SDG 6), which seeks to ensure the availability and sustainable management of water and sanitation for all. This study demonstrates that rainwater harvesting can play a pivotal role in achieving water security in commercial buildings, offering a practical solution to address Dhaka's water scarcity.

The case study of the LEED Platinum-certified commercial building on Gulshan Avenue showcases how rainwater harvesting when combined with efficient water use strategies, can reduce water demand by up to 50%. This model enhances water security and provides a replicable framework for other commercial projects, contributing to Dhaka's broader efforts to achieve SDG 6. Despite the growing popularity of LEED certification in the RMG sector, driven by buyer demands and compliance requirements, there remains a significant knowledge and research gap regarding the integration of rainwater harvesting in commercial buildings.

FUTURE WORK / REFERENCES

This study helps fill that gap by highlighting the benefits of rainwater as an alternative water source. However, further research is needed to optimize the application of rainwater harvesting systems in urban commercial contexts. Expanding on this work will be crucial for scaling sustainable water management practices, contributing to water security and the broader SDG targets. This pioneering case study sets the foundation for future research that can drive policy change and foster more sustainable development in Dhaka's commercial sector.

References:

Ahmed, S., & Nazmunnahar. (2015). FEASIBILITY OF RAINWATER HARVESTING IN SOLVING WATER CRISIS DHAKA CITY. IJRET: International Journal of Research in Engineering and Technology, pp. 2321–7308.

Akram, W., Niyommaneerat, W., Phetrak, A., & Kittipongvises, S. (2024). A Review on Water Security in Dhaka City, Bangladesh: Calling for Ensuring Sustainability. Applied Environmental Research, 46(2). https://doi.org/10.35762/AER.2024024

Akter Jahan, S. (2023). Bangladesh Development Update, New Frontiers in Poverty Reduction. www.worldbank.org/bd

Atiur Rahman. (2023, February 28). LDC Graduation: Implications for Bangladesh beyond 2026. Https://Www.Thedailystar.Net.

Environment, C. C. and D. S. (ECDS) C. (2017). Environment Climate Change and Disaster Statistics (ECDS) Cell.

Hossain, M., Sen, B., & Sawada, Y. (2013). Jobs, Growth, and Development: Making of the "Other" Bangladesh.

Islam, M., Van Camp, M., Hossain, D., Sarker, M. M. R., Khatun, S., & Walraevens, K. (2021). Impacts of large-scale groundwater exploitation based on the long-term evolution of hydraulic heads in Dhaka city, Bangladesh. Water (Switzerland), 13(10). https://doi.org/10.3390/w13101357

Radtke, K., & Weller, D. (2021). The WorldRiskIndex 2021 (pp. 41–50).

WASA. (2021). VISION TO TURN AROUND GO GREEN AND GO DIGITAL.

World Population Review. (2024). Dhaka, Bangladesh Population 2024. https://worldpopulationreview.com/cities/bangladesh/dhaka