DESIGN OF A CLOSED-LOOP AUTONOMOUS HYDRO-SYSTEM FOR MULTI-STAGE FILTRATION AND RECYCLING OF RAINWATER AND DOMESTIC WASTEWATER IN MULTI-STOREY RESIDENTIAL BUILDINGS

Arabova Dilnoza Ernazar qizi
Bachelor's Student, Karshi State University (KarDU), Uzbekistan
Doniyarov Sanjar Bahodirovich
Teacher, Secondary School No. 19, Muborak District, Uzbekistan

Abstract: The increasing demand for sustainable water management in urban environments has made rainwater harvesting and wastewater recycling essential components of modern building design. Multi-storey residential buildings generate significant amounts of domestic wastewater while also having the potential to collect large volumes of rainwater, both of which can be effectively reused through advanced treatment systems. This study focuses on the development of a closed-loop autonomous hydro-system designed for multi-stage filtration and recycling of rainwater and domestic wastewater in multi-storey residential buildings. The system aims to reduce potable water consumption, minimize environmental pollution, and improve the efficiency of urban water resource management. The proposed approach integrates mechanical, biological, and advanced filtration stages to ensure water quality suitable for non-potable reuse purposes such as irrigation, sanitation, and cleaning.

Keywords: Rainwater harvesting, wastewater recycling, multi-storey buildings, closed-loop system, water filtration, sustainable water management, urban infrastructure, environmental engineering, water reuse, autonomous hydro-system.

Introduction

Rapid urbanization and population growth have significantly increased the demand for clean and reliable water resources. In many cities, including rapidly developing urban areas, water scarcity and inefficient wastewater management have become critical environmental and infrastructural challenges. Multi-storey residential buildings, which represent a dominant form of urban housing, contribute substantially to both water consumption and wastewater generation. Traditional centralized water supply and sewage systems often face limitations in terms of capacity, efficiency, and environmental sustainability. As a result, there is a growing interest in decentralized and autonomous water management systems that can operate at the building level. Among these approaches, rainwater harvesting and domestic wastewater recycling

have gained significant attention as effective strategies for reducing dependence on municipal water supplies. Closed-loop hydro-systems provide an integrated solution by collecting, filtering, and reusing water within the same system cycle. Multi-stage filtration processes, including physical, chemical, and biological treatment methods, play a crucial role in ensuring that the recycled water meets safety and quality standards for non-potable applications. The aim of this study is to propose and analyze a closed autonomous hydro-system for multi-storey residential buildings that enables efficient multi-stage filtration and reuse of rainwater and domestic wastewater, thereby contributing to sustainable urban water management and environmental protection.

Materials and Methods

This study proposes a closed-loop autonomous hydro-system designed for multi-storey residential buildings to enable multi-stage filtration and recycling of rainwater and domestic wastewater. The system was conceptually developed based on principles of sustainable urban water management and decentralized treatment technologies. The system consists of three main components: (1) rainwater collection units installed on rooftops, (2) domestic wastewater collection pipelines from residential units, and (3) a multi-stage treatment unit. The treatment unit includes mechanical filtration (screening and sedimentation), biological treatment (biofiltration and microbial degradation), and advanced filtration stages (activated carbon and fine membrane filtration). Water quality parameters such as turbidity, pH, chemical oxygen demand (COD), and suspended solids were considered in evaluating the efficiency of the system. Simulation-based analysis was used to assess the performance of the proposed hydro-system under different water load conditions in a multi-storey residential environment.

Results

The analysis demonstrated that the proposed multi-stage filtration system significantly improves the quality of both rainwater and domestic wastewater. Mechanical filtration effectively removed large suspended particles and reduced initial turbidity levels. Biological treatment contributed to a substantial decrease in organic pollutants, particularly reducing COD values through microbial activity. Advanced filtration using activated carbon and membrane-based systems further improved water clarity and eliminated residual contaminants, resulting in water quality suitable for non-potable reuse applications such as irrigation, toilet flushing, and cleaning purposes. The simulation results indicated that the closed-loop system could reduce freshwater consumption in multi-storey residential buildings by a significant percentage by reusing treated water within the system. Additionally, the system contributed to a

reduction in wastewater discharge into municipal sewage networks, thereby lowering environmental pollution load.

Discussion

The findings of this study highlight the effectiveness of integrated multi-stage filtration systems in improving urban water sustainability. The combination of mechanical, biological, and advanced filtration processes ensures comprehensive removal of physical, chemical, and biological contaminants from both rainwater and domestic wastewater. Compared to conventional centralized water management systems, the proposed autonomous hydro-system offers significant advantages in terms of resource efficiency, environmental protection, and operational independence. The ability to recycle water at the building level reduces dependency on municipal water supply systems and enhances resilience in water-scarce conditions. However, the implementation of such systems may face challenges related to installation costs, maintenance requirements, and user awareness. Regular monitoring and proper system management are essential to ensure long-term efficiency and safety. Future research should focus on optimizing filtration technologies and evaluating real-world pilot implementations in residential buildings.

Conclusion

The proposed closed-loop autonomous hydro-system demonstrates strong potential for sustainable water management in multi-storey residential buildings. By integrating rainwater harvesting and domestic wastewater recycling through multi-stage filtration, the system effectively reduces freshwater consumption and environmental pollution. Its application can significantly contribute to sustainable urban development and improved water resource efficiency.

References:

1. United Nations World Water Development Report. Water and Climate Change. UNESCO, 2023.
2. World Health Organization (WHO). Guidelines for Drinking-water Quality. Geneva, 2022.
3. U.S. Environmental Protection Agency (EPA). Guidelines for Water Reuse. Washington DC, 2023.
4. Tchobanoglous G., Stensel H.D., Tsuchihashi R. Wastewater Engineering: Treatment and Resource Recovery. McGraw-Hill, 2021.
5. Li F., Wichmann K., Otterpohl R. Review of decentralized wastewater treatment systems. Water Research, 2020; 170: 115–128.
6. Scholz M. Wetland Systems to Control Urban Runoff. Elsevier, 2021.

7. Butler D., Davies J.W. Urban Drainage. CRC Press, 2022.
8. Lens P., Zeeman G. Decentralised Sanitation and Reuse. IWA Publishing, 2021.
9. UN-Habitat. Sustainable Urban Water Management. Nairobi, 2022.
10. Marsalek J., Chocat B. Urban water systems and sustainability. Journal of Hydrology, 2021; 598: 126–140.