



Analysis of the Quality and Time of the Rainwater and Greywater Management System in Government Buildings in East Java

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ARTICLE INFO

Keywords: Greywater,
Wastewater, Building

Received : 27, October
Revised : 29, November
Accepted: 31, December

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ABSTRACT

The East Java Provincial Public Housing, Settlement Area, and Public Works Office served as the study's location. This data reveals a discernible disparity in height and size between the two structural portions. A greywater management system, on the other hand, is made to treat and recycle wastewater from building or household operations, such as water from laundry machines, sinks, and showers, but not toilet waste (also known as blackwater). In comparison to blackwater, greywater usually has lower levels of soap, detergent, oil, fat, and organic waste as well as fewer germs. As a result, with the right care, it can be used again. Depending on the size and use of the building, eco-friendly buildings can cut their potable water usage by 30 to 50% by implementing greywater management.

INTRODUCTION

The availability of clean water supplies and the environment's ability to handle wastewater have been severely strained by Indonesia's fast urban infrastructure development and population increase. Water usage and the production of household garbage are significantly influenced by the construction industry, especially with regard to high-rise buildings. According to national regulations like Minister of Public Works and Public Housing Regulation No. 21 of 2021, which aims for water savings of at least 10% of raw water consumption, the Green Building (GWB) concept has been established as a strategic solution to minimize environmental impacts and optimize resource efficiency.

The use of alternative water management techniques, especially rainwater harvesting (RWH) and greywater recycling (non-toilet wastewater), is one of the key pillars in attaining water efficiency at BGH. Greywater recycling lessens the burden of waste disposal and reliance on PDAM water, while the RWH system makes use of Indonesia's high rainfall for non-potable uses (such flushing and irrigation). It has been demonstrated that the hybrid system, which combines these two technologies, greatly lowers the amount of clean water used, even reaching high levels of water conservation efficiency in case studies in a number of buildings (Farida & Aryuni, 2020; Mardiaman & Siahaan, 2024).

One of the famous government structures marketed as a test project for BGH implementation at the provincial level is the Provincial Cipta Karya Green Building. This building, which falls under the Directorate General of Human Settlements, must not only adhere to green certification requirements but also make the best use of sustainable technologies. However, the current implementation of RWH and greywater recycling systems in government buildings frequently faces particular challenges, such as suboptimal technology adoption, a lack of operational awareness, and management barriers to sustainable system maintenance, despite normatively established water efficiency targets (Jaya et al., 2024).

Thus, a thorough examination of the Cipta Karya Provinsi Green Building's rainwater collection and greywater recycling is necessary. In order to establish the possibility of a more comprehensive and integrated system implementation, this research is essential for determining the current state of the system, from installation design and operational capability to construction and maintenance management limits. An assessment of the water balance, savings forecasts, and technical suggestions specific to the building's features and regional rainfall will all be included in this possible analysis.

Water conservation, including the use of Rainwater Harvesting (RWH) technology and greywater recycling, is the main emphasis of the study of water system implementation and efficiency in green buildings. Using water-saving measures and recycling installations is necessary to achieve significant water savings when implementing new green construction concepts. According to research, installing efficient water features in a variety of office buildings can save a significant amount of clean water – up to 28.74% of the total PDAM water demand, according to some studies (Mardiaman & Siahaan, 2024). Additionally, by integrating RWH systems, these savings can be further increased. By using

rainwater harvesting facilities, potential daily water savings can reach an average of 30.57%, directly lowering operational costs and reliance on traditional water sources.

THEORETICAL REVIEW

Green building (BGH) application is evident not only in system design but also in adherence to performance criteria and current legislation. In an attempt to meet national climate targets, the government has set a minimum water savings target of 10%, demonstrating its commitment to sustainable growth (Info Republik, 2022). Stormwater management and water recycling are specific requirements for raising water efficiency scores in assessment standards as Greenship by GBCI (Bobo et al., 2023). In order to support the accomplishment of set water conservation goals, construction management reviews must guarantee that piping and recycling systems, including the choice of water-saving fixtures, are constructed in compliance with hydraulic requirements.

During this time, a lot of study was done on hybrid or mixed systems to get maximum efficiency. Rainwater harvesting combined with greywater recycling has been shown to be an excellent method for optimizing the supply of non-potable water requirements, including cooling towers, irrigation, and toilet flushing (Jaya et al., 2024). This is significant because greywater, or non-toilet wastewater, makes up between 60% and 80% of all wastewater in residential and commercial buildings, making it the most promising source of recycled water (Bangka Belitung Public Works and Housing Agency, 2023). The domestic water cycle in buildings can be closed by properly treating extra greywater from flushing requirements and using it for groundwater conservation through infiltration wells.

Particularly when comparing system performance between the rainy and dry seasons, the integrated recycling system's performance demonstrates encouraging outcomes. When RWH is maximized, water conservation efficiency can rise to 69.0% during the rainy season, compared to just 30.1% during the dry season when relying exclusively on greywater recycling, according to case studies from many institutions (Farida & Aryuni, 2020). This demonstrates that seasonal factors have a significant impact on system performance, necessitating thorough water balance analysis to maximize rainwater retention capacity and greywater treatment system design for year-round operation.

Digitalization is also becoming more and more important in the implementation of water systems. Recent developments show a move toward smart water management systems that use IoT (Internet of Things) technology to track water amount and quality in real time (Movva, 2023). In addition to increasing the efficiency of non-potable water savings, the use of sensors in RWH and greywater recycling systems allows for automatic leak detection and water usage optimization, which also makes maintenance easier (IKN Authority, 2024). Therefore, a combination of technical efficiency, construction management compliance, and the integration of the most recent smart technologies must be used to evaluate the effectiveness of the water system installation at the Provincial Cipta Karya Green Building.

As population increase, urbanization, and the effects of climate change put more strain on natural resources, the idea of "green buildings" was born. Green buildings are those that, throughout their planning, construction, operation, and maintenance, limit adverse effects on the surrounding environment, prioritize the health and comfort of its occupants, and make efficient use of resources (water, energy, and materials). This strategy places a strong emphasis on indoor air quality, waste management, water conservation, energy efficiency, and other sustainability factors.

The use of rainwater and greywater management systems in green buildings has been the subject of extensive national and international research. Understanding technology advancements, performance evaluation techniques, and elements impacting effective implementation requires reviewing prior studies.

The research area's installation of a rainwater collecting system, which generates extra water sources, particularly for household purposes, is consistent with findings from studies conducted in other regions employing the same technique. In Masohi City, Central Maluku Regency, a reservoir tank with dimensions per family was designed to hold rainwater, and Durensari Village, Bagelen District, Purworejo Regency, can save 214 m³ of water annually, or 4% of the total water consumption in residential areas (Marwoto et al., 2021). According to research on rainwater consumption, a roof may collect 3 m³ of rainwater (Tiwery et al., 2022). It is undoubtedly confirmed by a number of correlations with related studies that this approach is successful in adding more water sources. (Pamungkas Hayatining et al., 2023)

Grey water, condensate water, and rainwater can be utilized to meet the building's daily needs, reducing water consumption by 39,975.66 m³ in ten years, or 66.07%, according to the analysis of alternative water sources. Water usage expenditures can be lowered by 60.74% with an operational cost savings of Rp 391,761,636. for the Rp 486,902,490 necessary capital investment. (Biyanto and others, 2016).

TSS 0.89%, BOD 69.11%, COD 87.24%, Ammonia 18.35%, Oil and Fat 95.16%, and pH increase to 21.08% are some of the effective filtration methods to lower water pollutant levels. However, this method can only raise the pH from 5.64 to 6.87 in order to meet the requirements of the Minister of Environment and Forestry Regulation No. 68 of 2016 regarding domestic wastewater quality standards. The findings of this study can be used as a pretreatment for domestic wastewater treatment to the next stage of domestic wastewater treatment; further research to pay attention to and improve the effectiveness of filtration, which includes the volume of the container and the thickness of each filter media; and comprehensive studies and analysis related to the examination of domestic wastewater quality. (Faradila and others, 2023).

Following treatment with a filtration system, wastewater levels were significantly reduced for a number of evaluated parameters, with corresponding percentage reductions in BOD (77.33%), COD (79.78%), and sulfate (31.23%). In the meantime, because there were no impurities from the first treatment, TSS (oil and grease) values did not drop. (Afrhiani and others, 2020)

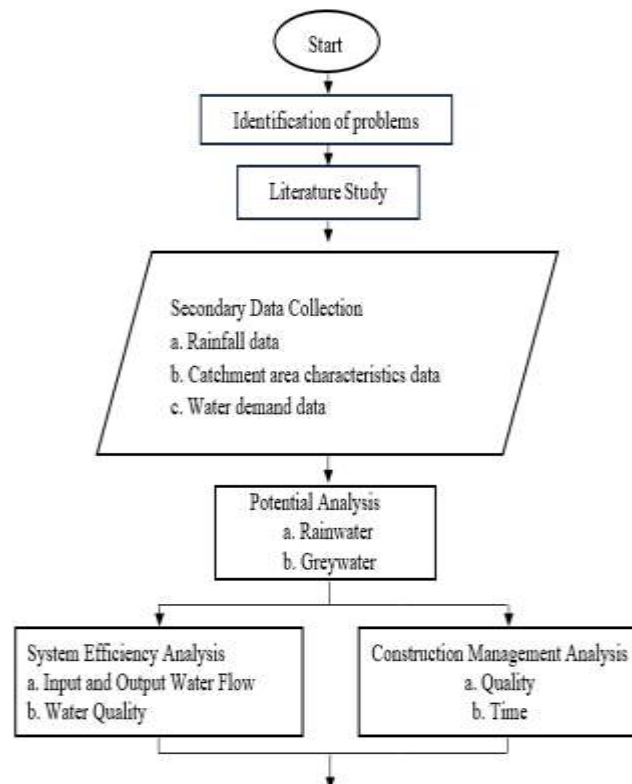
Constructed Wetland technology with a Vertical Subsurface Flow System is the suitable and effective method for treating greywater wastewater at the Taman Candiloka Housing Complex in Ngampelsari Village, Candi District, Sidoarjo Regency (Afrhiani et al., 2020).

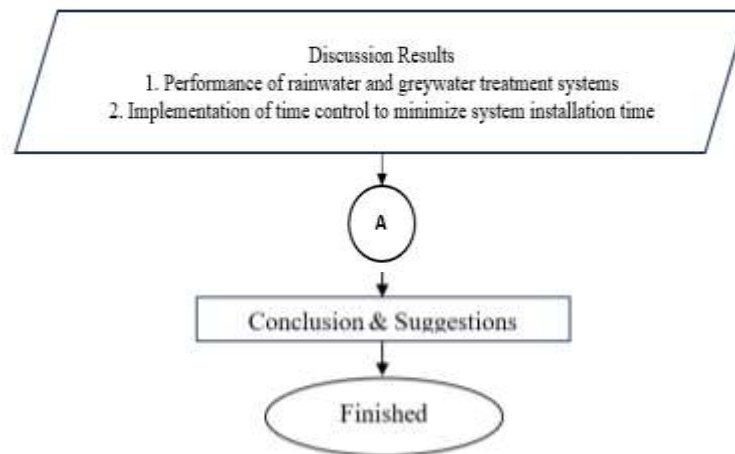
An equalization tank unit and an SRAB unit were added based on the redesign results, resulting in a greywater storage volume and unit size that complies with SNI 8455:2017. The wastewater distribution system has also changed as a result of the inclusion of the SRAB unit, including pipe slopes and elevation variations. The route and distance differ from the current Gunung Anyar Surabaya Rusunawa circumstances, necessitating changes to the wastewater distribution system. The two treatment unit zones to the right and left of the Rusunawa will comprise the field's redesign implementation. This is because there is not much vacant land at Gunung Anyar Rusunawa. Greywater waste should be taken into account while planning the WWTP to ensure that the waste released satisfies the quality requirements of East Java Governor's Regulation No. 52 of 2014. (Afrhiani and others, 2020).

In 2014, the UNDIP Campus area's average water needs were 5,920 liters per second, the maximum daily needs were 6,808 liters per second, and the peak-hour needs were 9,955 liters per second. In 2014, the UNDIP Campus area used 29541 m³, or 2.23 lt/sec, of groundwater. Roads and infiltration gardens are part of the UNDIP Campus area's rainwater harvesting system, which consists of a cistern building and infiltration wells. With a volume of 240 m³ and concrete quality f'c 15, the Cistern Building is intended to be constructed using gutters.

METHODOLOGY

The following figure shows the flowchart for the stages of research implementation:





Among the techniques employed are:

- Field observations to ascertain the current state of the greywater and rainwater management system.
- Technical document analysis to gather system specifications, capacity, and design data.
- Conducted structured interviews with construction implementers and management.
- Field measurements of actual water usage, flow rate, and storage volume. Gathering and processing the acquired primary and secondary data is the first stage. A timetable is part of the information gathered.

The following phases of data analysis were carried out:

- Rainwater and Greywater Potential Analysis: Based on the number of users and kind of activity, a formula is used to estimate greywater discharge and determine the volume of rainwater catchment. Technical Document Studies: Getting system specifications, capacity, and design data.
- System Efficiency Analysis: evaluating system losses and comparing actual and prospective utilized quantities.
- Construction Management Analysis: Examining the system's planning, execution, and monitoring procedures using observations and interviews to determine how well it was implemented.

This study will be carried out for eight weeks, starting in the first week of January 2026, and ending with the completion of the thesis report.

The following are the primary variables in this study:

1. Technical Factors

Rainwater potential (capture volume); capacity and storage volume of rainwater harvesting systems; discharge and volume of greywater generated; and system efficiency (comparison of potential and actual utilization)

2. Variables related to management:

- Planning and execution of system construction;
 - Procedures for system monitoring and maintenance;
 - Limitations and hazards in system execution
- Local rainfall, roof area, runoff coefficient, greywater outflow, and information on the building's PDAM water usage were among the parameters noted.

Field observations, building manager interviews, measurements of current systems, and field photographic recording are examples of primary data used in this study.

- Secondary Data: building planning drawings, budget documents (RAB), working drawings, rainfall data from the local BMKG (Meteorology, Climatology, and Geophysics Agency), and pertinent literature and regulations.

RESULTS AND DISCUSSION

The East Java Provincial Public Housing, Settlement Area, and Public Works Office building, situated at Jl. Gayung Kebonsari No. 169, Gayungan, Gayungan District, Surabaya, East Java, was the site of this study. There are three main roof structures in the building facility, however in this instance, I just looked at the Main Building and the West Wing Building. The Main Building is the bigger building, measuring 22.00 meters in width and 37.30 meters in length. This structure has four levels and a total floor space of about 820.6 m². The West Wing Building, on the other hand, is 9.28 meters wide and 24.57 meters long. With just two stories, this construction is lower and has a total floor space of about 228.00 m². Overall, the data indicates that the two sections of the building differ significantly in terms of size and vertical capacity.

A greywater management system, on the other hand, does not contain water from toilets (blackwater). Instead, it is an attempt to clean and reuse wastewater from household or building activities, such as from sinks, showers, and washing machines. After treatment, greywater can be used again because it has fewer germs than blackwater and contains soap, detergent, oil, fat, and organic compounds in small amounts. Depending on the building's size and activity, greywater management in green buildings can reduce the amount of pure water used by up to 30–50%. Sand or multimedia filtration, sedimentation of solid particles, and first filtering to eliminate big pollutants are all part of the treatment process.

The GBCI Greenship guidelines, PUPR Ministerial Regulation No. 21 of 2021, Ministerial Regulation No. P.68/Menlhk/Setjen/Kum.1/8/2016 concerning domestic wastewater standards, and WHO guidelines for the use of recycled water are examples of regulations pertaining to greywater management in Indonesia. International standards like BS 8525 (United Kingdom) and NSF/ANSI 350 (United States) are used as references for environmental health, water quality criteria, and system design. Aerobic biofilters for small to medium-sized buildings, membrane bioreactors (MBR) for large buildings, and artificial wetlands that use aquatic plants for natural filtration are examples of frequently used technology. Implementing greywater treatment systems has several advantages, such as lower clean water and operating costs, less domestic waste, more water conservation points in green building evaluations, and assistance in achieving sustainable development principles through efficient use of water resources and fewer environmental burdens.

rainfall harvesting is a device that gathers and uses rainfall from the surface of buildings or land for a variety of functions, especially non-potable ones like washing areas, gardening, and toilet flushing. Because it makes use of

naturally occurring water sources, lessens reliance on PDAM water, and eases the strain on urban drainage systems, this approach is among the most straightforward and efficient ways to conserve water.

Capturing, channeling, filtering, storing, and distributing rainwater for future use is the fundamental idea of a rainwater harvesting system. In general, this system is made up of the following major parts:

- A collection region where rainwater falls, typically a building's roof. The amount of rainwater that can be collected will depend on the size and kind of roof.
- Rainwater is directed from the roof to a storage system by collection channels, such as gutters and downpipes. To avoid excessive runoff, these channels must be built with a suitable slope and capacity.
- A first-flush diverter, which cleans the roof of the first precipitation that usually carries dust and grime.
- Rainwater is stored in a storage tank. Depending on the site circumstances and building design, tanks may be situated underground (underground tank) or above ground (ground tank).
- A filtration and distribution system that distributes rainwater to locations of usage after filtering it to fulfill non-potable water quality criteria.

Rainwater management in Indonesia is governed by a number of laws, including:

- Ministerial Regulation No. 12 of 2014 about the Implementation of Urban Drainage Systems, which promotes the use of rainwater harvesting systems to lessen runoff.
- SNI 8456:2017 about Procedures for developing Urban Drainage Systems, which offers recommendations for developing retention systems and estimating rainwater discharge.
- Ministerial Regulation No. 21 of 2021 about Green Building Assessment mandates the use of rainwater as a component of water saving initiatives.

Guidelines for designing rainwater collecting systems are also provided by international standards such AS/NZS 3500 (Australia) and BS 8515 (United Kingdom).

The following are some advantages of putting this system into place: • Reducing PDAM water consumption, which lowers building operating expenses.

- Managing puddles and rainwater flow around structures.
- Adding to the green building assessments' Water Conservation score.
- Making the building more resilient to drought or disruptions in the availability of clean water.

Rainwater harvesting technologies are therefore crucial to the implementation of green buildings, particularly in government buildings with huge roof areas and high non-potable water requirements.

Except for toilets (blackwater), greywater is wastewater from residential or construction activity. Sinks, showers, baths, washing machines, and kitchens are the main sources of greywater. Soap, detergent, oil, grease, organic particles,

and residues of common home chemicals are typically found in small amounts in greywater. After going through a certain treatment procedure, greywater can be utilized again because it has comparatively less pathogens than blackwater.

Greywater management is an essential water conservation tactic in the context of green buildings. Reusing greywater can reduce the amount of pure water used by up to 30–50%, depending on the size and occupancy of the facility. Typically, treated greywater is utilized for non-potable uses like cleaning building areas, watering gardens, and flushing toilets.

In order to safely reuse the water, greywater treatment attempts to eliminate suspended particles, organic debris, oil, and grease as well as lower the concentration of pollutants. There are multiple steps in the treatment principle, specifically:

- **Initial Screening:** Large impurities like hair, food crumbs, and rags are filtered out of greywater. This step keeps later processes from becoming clogged.

- **Sedimentation:** The filtration process is less burdened when heavier solid particles settle in the holding tank.

There are three categories of biological treatment and filtration:

- To eliminate some organic matter and fine particles, sand or multimedia filtering is utilized.

- Membrane bioreactors (MBR) or aerobic biofilters are frequently utilized to drastically lower BOD and COD levels.

- **Cleaning:** Depending on the system's size and the set water quality criteria, the last step usually uses ozonation, UV radiation, or chlorination to lower the quantity of harmful microbes.

The final product of this procedure is known as treated greywater, and its quality satisfies the requirements for reuse, particularly for non-potable uses.

Effective construction management has a significant impact on the application of green building concepts in addition to technical planning and architectural design. The process of organizing, planning, carrying out, and managing resources is known as construction management.

The construction management team must make sure that the design papers and implementation plans incorporate green building principles at an early stage of the project. This entails choosing energy and water-saving technologies, figuring out how to collect rainfall and reuse greywater, and modifying work schedules to facilitate the installation of these systems. Success depends on coordination between the architectural, civil, MEP, and environmental disciplines.

The initial investment costs of green technology, which are typically higher than those of conventional systems, are one of the biggest obstacles to its implementation. Through life cycle cost analysis, the selection of suitable technology for scale, and cost control during implementation, construction management contributes to budget optimization. In order to prevent the integration of rainwater harvesting and greywater systems from interfering with the primary work sequence, scheduling must also be modified.

Rainwater and greywater management system installation must adhere to relevant technical standards. The construction management team is in charge of carrying out routine inspections, making sure that supplies and machinery fulfill requirements, and commissioning systems before handover.

To ensure sustainability, certain measures are needed when implementing green building systems in government projects like the Provincial Cipta Karya Building. Among the most important tactics are:

- Including green ideas in contracts so that building service providers are required by law to put these systems in place.

- Outreach and training for field workers, since some contractors are unfamiliar with rainwater gathering and greywater reuse methods.
- Strict oversight by construction management, particularly with regard to the installation of water treatment units, storage tanks, and pipes.
- Building users should be involved from the beginning so that the systems can be used sustainably once the project is finished.

The quality of construction has a big impact on how well rainwater and greywater management systems work. The system may not operate at its best due to installation mistakes, improper material selection, or insufficient testing. As a result, construction management is crucial to ensure that green building technologies actually produce the desired results.

CONCLUSION AND RECOMMENDATION

The following conclusions can be made based on the analysis done on the conversion of the East Java Provincial Public Works Agency Office Building into a green building. An evaluation of the rainfall and greywater treatment system's effectiveness in the East Java Provincial Public Works Agency Office Building retrofitting project, which uses a combination of rainwater and PDAM water for clean water use. An examination of the use of time control to reduce installation system consumption in the East Java Provincial Public Works Agency Office Building retrofitting project.

FURTHER STUDY

Based on the analysis conducted on the conversion of the East Java Provincial Public Works Agency Office Building into a green building, several conclusions can be drawn. First, the evaluation of the rainwater harvesting and greywater treatment systems demonstrates that the combined use of rainwater and PDAM water is effective in supporting clean water needs within the retrofitted building. This approach contributes to improved water efficiency and reduced reliance on conventional water sources. Second, the implementation of time control systems in building installations proves effective in minimizing system usage, thereby reducing water and energy consumption. Overall, these strategies support the successful integration of sustainable water management and operational efficiency in the green building retrofitting project.

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