e-ISSN: 2229-8568

A Case Study on Greywater Recycling Process in High-Rise Developments: Operational Insights from Clearpoint Residencies, Sri Lanka.

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Abstract

This case study investigates the design, integration, and operational performance of a greywater recycling system within Clearpoint Residencies, a pioneering sustainable high-rise residential project located in Colombo, Sri Lanka. The purpose of the study is to identify the process of the greywater recycling using the Andrew Campbell's Operating Model Canvas. This includes evaluating six key areas of process, organization, location, information, suppliers, and management systems. The study adopted a qualitative case study approach, using semi-structured interviews with project stakeholders and a review of technical and institutional documents. Analysis was guided by the Operating Model Canvas framework, examining six operational dimensions. Data were thematically analyzed to identify implementation challenges, strengths, and strategic responses. The findings reveal that Clearpoint Residencies successfully implemented a greywater recycling system that collects water from showers and washbasins, treats it through anaerobic and aerobic processes, and reuses it for toilet flushing and landscape irrigation. And this study also identify the key main challenges associate with this process. The study's originality lies in applying the Operating Model Canvas to analyze greywater system operations in a high-rise building in Sri Lankan context. This study offers practical insights for replicating sustainable water management strategies in urban developments, emphasizing the need for integrated planning, technical expertise, and stakeholder alignment.

Keywords:

Challenges, Clearpoint Residencies, Greywater Recycling, Operating Model Canvas, Water Conservation.

Article History

Received: 4 May 2025
Accepted: 10 March 2026
Published: 26 August 2026

e-ISSN: 2229-8568

1. INTRODUCTION

In the 21st century, fresh water scarcity has remained a defining global challenge, exacerbated by rapid urbanization, climate change, and population growth. This scarcity underscores the urgent need for effective water conservation methods to sustainably manage this vital resource for future generations (Van de Walle et al., 2023). Among these methods, greywater recycling stands out as a pivotal solution. Greywater recycling involves treating and repurposing wastewater from sources like sinks, showers, and laundry, diverting it from traditional sewage systems for non-potable uses such as irrigation or toilet flushing (Kordana-Obuch et al., 2023). By harnessing this alternative water source, greywater recycling not only alleviates strain on freshwater supplies but also reduces the burden on wastewater treatment infrastructure.

Aligned with the Sustainable Development Goals (SDGs), particularly SDG 6: Clean Water and Sanitation, the pursuit of water conservation is integral to promoting universal access to safe and affordable drinking water and sanitation facilities (United Nations, 2015). Integrating water conservation practices, including greywater recycling, into broader sustainability initiatives contributes significantly to advancing this global agenda.

In addition, initiatives such as Leadership in Energy and Environmental Design (LEED) certification recognize and incentivize water conservation efforts in the built environment. LEED certification, a widely recognized green building rating system, incorporates specific criteria related to water efficiency and conservation (Karakhan, 2016). Projects pursuing LEED certification prioritize strategies such as greywater recycling systems, water-efficient fixtures, and landscape irrigation optimization to minimize water consumption and promote sustainability (Karakhan, 2016). Within this context, initiatives like the GREENSL® Rating System underscore the pivotal role of water efficiency in sustainable development. This renowned rating system, designed to evaluate the environmental performance of buildings and infrastructure, places particular emphasis on optimizing water usage.

Although greywater recycling has been acknowledged as an effective mechanism under waste water conservation, studies focused on the system installation, functioning as well as the contextual challenges of implementing these systems are lacking in high-rise residential buildings in the South Asian as well as in the Sri Lankan context. Therefore, this study aimed at examining the process, organization, location, information management, suppliers, and management system of the greywater recycling mechanism implemented at the Clearpoint Residencies, Sri Lanka, as well as the challenges faced by them when implementing and functioning the system.

2. LITERATURE REVIEW

2.1 Definition of Grey Water

Greywater is the term used to describe the relatively clean wastewater generated from domestic activities such as bathing, washing clothes, and kitchen use, excluding sewage water from toilets. It constitutes a substantial portion of household wastewater, accounting for nearly 50-80% of residential wastewater (Hasan et al., 2015). Unlike blackwater, greywater typically contains lower concentrations of pathogens and organic pollutants, making it a valuable resource for reuse and recycling applications (Friedler, 2004). Recent building-focused reviews also report that greywater can represent a similarly large share of total domestic wastewater depending on occupancy patterns and building type and recent literature increasingly categorises greywater into "light greywater" (showers, baths, washbasins) and "dark greywater" (kitchen sinks and laundry), because dark greywater typically contains higher loads of organics, oils/grease, and household chemicals, requiring more robust treatment (Niewitecka & Żubrowska-Sudoł, 2025).

This water is characterized by its composition of soaps, detergents, and food particles, which make

e-ISSN: 2229-8568

it suitable for non-potable purposes such as irrigation, toilet flushing, and landscaping after appropriate treatment (Gross et al., 2015). More recent studies also highlight emerging constituents such as microplastics, endocrine-disrupting compounds (EDCs), and other micropollutants which influence treatment selection and reuse safety (Budeli & Sibali, 2025). Greywater reuse offers significant environmental and economic benefits, including reducing freshwater demand, decreasing wastewater discharge, and contributing to water conservation, especially in water-scarce regions (Al-Jayyousi, 2003).

While greywater holds great potential for sustainable water management, its reuse must adhere to stringent treatment and safety protocols to minimize health risks and environmental impacts. Research into effective greywater treatment systems has grown, focusing on biological, physical, and chemical processes to ensure compliance with water quality standards (Ghaitidak & Yadav, 2013).

2.2 Advantages of Greywater Reuse

Greywater reuse offers numerous advantages, particularly in addressing water scarcity and enhancing sustainability in urban environments. One of the primary benefits is water conservation; studies indicate that greywater recycling can reduce freshwater consumption by up to 48%, significantly alleviating water shortages, especially in low-income communities (Mekonnen & Hoekstra, 2016).

This reduction is crucial as urban areas face increasing pressure on their water supplies due to population growth and climate change. Moreover, greywater reuse contributes to environmental protection by decreasing the volume of wastewater entering treatment facilities, which are often overburdened. This not only mitigates the risk of untreated wastewater polluting natural ecosystems but also reduces the operational costs associated with wastewater treatment (Madzaramba & Zanamwe, 2023).

Additionally, greywater systems can provide economic benefits by lowering water bills for households and reducing the need for extensive infrastructure investments in new water supply systems (Isaksson et al., 2023). Economic evaluations also show that combined on-site systems (e.g., greywater reuse with rainwater harvesting) can improve overall water-supply efficiency and reduce dependency on potable networks, strengthening the cost–benefit case in building applications (Ghisi & Freitas, 2024).

Greywater reuse can also strengthen building-scale water resilience by providing a reliable non-potable supply for activities such as toilet flushing and landscape irrigation, especially in water-stressed regions. Evidence from a university-building case reports measurable potable-water savings when treated greywater is reused approximately 12.67% potable-water saving for toilet flushing, and in some scenarios, irrigation demands (e.g., green roof/garden areas) can be fully met using greywater supply (Lanchipa-Ale et al., 2024).

Recent social-acceptance research similarly indicates strong community willingness for low-contact non-potable uses (especially toilet flushing and irrigation) when greywater is treated and the purpose is clearly explained; for example, one study recorded very high acceptance (around 77%) for treated greywater reuse in a settlement context (Madzaramba, 2024).

Further, greywater reuse aligns strongly with sustainability and green-building agendas (e.g., LEED/BREEAM), where water-efficiency interventions can support environmental performance targets and encourage adoption in new developments (Niewitecka & Żubrowska-Sudoł, 2025).

2.3 Disadvantages of Greywater Reuse

While greywater reuse offers significant environmental and economic benefits, it also presents notable challenges and disadvantages that must be addressed for safe and effective implementation. One primary concern is the potential for public health risks due to the presence of pathogens, organic matter, and chemical contaminants in untreated or inadequately treated greywater. Improper reuse can lead to the spread of waterborne diseases and soil contamination (Friedler, 2004).

Greywater reuse systems often require significant initial investment and maintenance costs, particularly for advanced treatment technologies such as membrane filtration or constructed wetlands. These costs may act as a barrier to adoption, especially in low-income settings (Ghaitidak & Yadav, 2013). Moreover, greywater contains high concentrations of salts, detergents, and oils, which can accumulate in soils, negatively affecting soil quality and plant health when used for irrigation over long periods (Al-Jayyousi, 2003).

Additionally, improper storage of greywater can lead to odor issues, mosquito breeding, and aesthetic concerns, reducing its acceptance among users. Regulatory challenges and lack of standardization in greywater treatment and reuse practices also limit its widespread adoption (Hasan et al., 2015).

Recent literature stresses that greywater is “variable and complex” and may contain broad contaminant mixtures (organic/inorganic pollutants, heavy metals, microbial agents), so treatment must be matched to the intended reuse and required safety levels (Budeli & Sibali, 2025).

Emerging contaminants are an increasing concern in greywater reuse, including endocrine-disrupting chemicals (EDCs), microplastics, and nanoparticles, which may not be fully removed by conventional treatment and may create longer-term ecological and health uncertainties (Budeli & Sibali, 2025)

2.4 Grey Water Quality

Greywater is frequently treated before reuse, although this is not always the case, and the level of treatment can differ significantly. While greywater may contain contaminants similar to those found in raw sewage, the concentrations are generally lower. For instance, it can have fecal coliforms and nutrients such as nitrogen and phosphorus (Allen, 2010).

Table 1: Possible Greywater Contaminants by Greywater Source

Greywater Source	Possible Contents
Automatic clothes washer	Suspended solids (dirt, lint), organic material, oil and grease, sodium, nitrates and phosphates (from detergent), increased salinity and pH, bleach
Automatic dishwasher	Organic material and suspended solids (from food), bacteria, increased salinity and pH, fat, oil and grease, detergent
Bathtub and shower	Bacteria, hair, organic material and suspended solids (skin, particles, lint), oil and grease, soap and detergent residue
Sinks, including kitchen	Bacteria, organic matter and suspended solids (food particles), fat, oil and grease, soap and detergent residue

Source: Allen, 2010

2.5 Greywater Reuse in High Rise Buildings in Other Countries

Greywater reuse in high-rise buildings has increasingly been adopted globally as a sustainable solution to address water scarcity and promote resource efficiency. Many nations have assessed greywater reuse practices, exploring technical methods and the associated health and environmental impacts.

In the USA, greywater reuse has been a focus since the 19^{th} century, with California pioneering regulations. By the 1980s, greywater reuse systems were piloted in high-rise areas, and a domestic reuse

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code was established in 1977. Arizona further promotes greywater use for non-potable purposes in urban developments (Ibrahim et al., 2014).

Japan mandates greywater recycling for high-rise buildings over 30,000 square meters or those capable of reusing 100 cubic meters per day. These systems, often complex, recycle water for toilet flushing and other non-potable uses, showcasing efficient integration in urban infrastructure (Ibrahim et al., 2014).

In Cyprus, dual plumbing systems introduced in 1999 allow greywater reuse for toilet flushing in high-rise buildings, supported by subsidies for system installations. Similarly, the UK has explored greywater reuse in multi-story buildings through pilot projects employing filtration and disinfection, although issues with maintenance and reliability remain challenges (Ibrahim et al., 2014).

3. CASE BACKGROUND

The Clearpoint Residencies, a 46-storey residential apartment situated in Rajagiriya, Colombo, Sri Lanka, stands as an embodiment of innovative project management methodologies tailored for sustainable development in urban architecture. Recently granted with the prestigious Platinum Rating Certification under the esteemed GREENSL Rating System for Built Environment, this architectural building underscores a pinnacle in eco-friendly design and operational functionality. The accolade, bestowed during the Annual Green Building Awards Ceremony 2018 hosted by the Green Building Council of Sri Lanka, highlights the Clearpoint Residencies' unwavering commitment towards fostering environmentally sound practices while ensuring occupants' well-being within a conducive indoor environment.

The Platinum Green Rating conferred by the Green Building Council of Sri Lanka not only validates Clearpoint Residencies' endeavors but also positions it as a global benchmark for sustainable constructions. As a forerunner of sustainable urban living, Clearpoint Residencies sets an exemplary standard for future residential developments, inspiring them to embrace eco-consciousness and innovation.

Conceived through a collaborative effort between Milroy Perera Associates and Maga Engineering, this residential edifice reflects the visionary ideals of esteemed Architect late Milroy Perera. Its most distinctive feature, the verdant terraces enveloping the facade, not only imbue the structure with a unique aesthetic appeal but also offer tangible benefits such as natural cooling, acoustic insulation, and shading. Furthermore, Clearpoint Residencies boasts an array of pioneering sustainability initiatives, including a comprehensive rainwater harvesting system, automated drip irrigation, greywater recycling, and efficient solid waste management. Additionally, the utilization of solar panels to power common areas, coupled with the provision of electric charging stations, underscores the commitment towards fostering a clean energy ecosystem among residents.

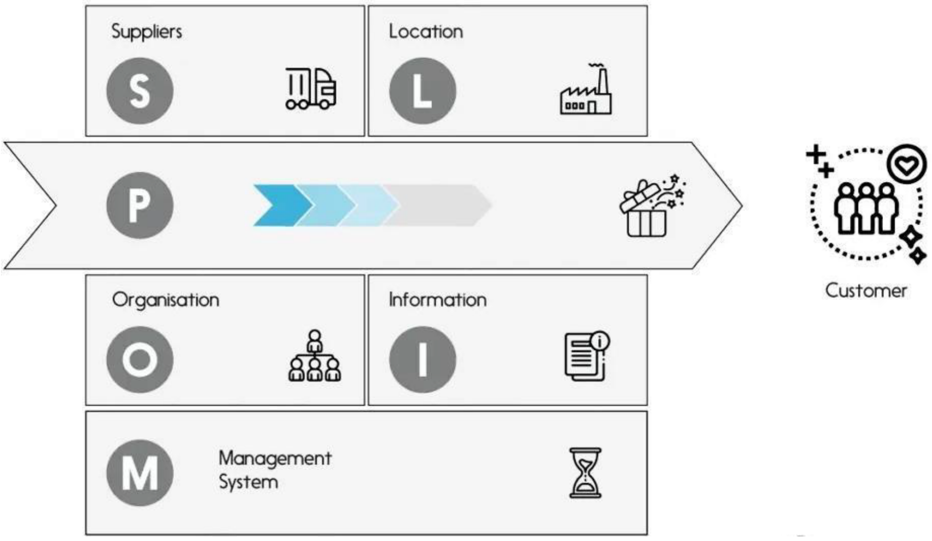
Beyond its striking vertical gardens, Clearpoint Residencies' sustainability ethos encompasses a spectrum of design, construction, and operational strategies aimed at mitigating environmental impact and enhancing resource efficiency. Research conducted by Asif et al. (2013) delves into various green building principles, including the integration of renewable energy sources like solar panels and the incorporation of energy-efficient appliances and building materials (Asif et al., 2013). Moreover, rainwater harvesting and greywater recycling systems, akin to those adopted at Clearpoint Residencies, significantly alleviate reliance on municipal water supplies. Concurrently, waste segregation and recycling initiatives foster a circular economy model, thereby minimizing landfill waste. By amalgamating these green building tenets, Clearpoint Residencies aspires to attain a diminished carbon footprint and foster a more sustainable urban landscape.

It is clear that the Clearpoint Residencies represents a paradigmatic shift in urban habitation, where richness and sustainability converge harmoniously. With its new design, unwavering commitment to environmental stewardship, and relentless pursuit of excellence, Clearpoint Residencies transcends the realm of mere infrastructure to embody the transformative potential of sustainable architecture.

4. FOLLOWED APPROACH

A comprehensive literature review was conducted to contextualize the study within global and local discourse on greywater recycling systems in high-rise developments. The review focused on peer-reviewed journal articles and relevant industry/institutional publications related to greywater generation, treatment technologies, reuse applications in buildings, operational risks, and management practices. Key search terms included "greywater reuse", "greywater recycling", "high-rise buildings", "on-site wastewater treatment", "non-potable reuse", and "urban water sustainability". Primary data were gathered through semi-structured interviews with the Project Manager and informal discussions with three professionals involved in the project. Participants were selected purposively based on their direct involvement in the planning, implementation, or operational oversight of the greywater system. A semi-structured format was used to ensure consistency across interviews while allowing follow-up questions. Interview topics covered system design intent, operational processes, maintenance practices, key challenges encountered, corrective strategies, and perceived performance of the system. Notes were taken during discussions, and information was treated confidentially. Secondary data were obtained from technical reports, architectural plans, and institutional documents. The study adopted the Operating Model Canvas framework to assess the system across six key operational dimensions (Operating Model Canvas - Andrew Campbell, Mikel Gutierrez, Mark Lancelott - Google Books, 2017). Data were analyzed using qualitative content analysis to identify operational challenges, strengths, and strategies applied at Clearpoint Residencies.

Figure 1: Andrew Campbell's Operating Model.



Source: Operating Model Canvas - Andrew Campbell, Mikel Gutierrez , Mark Lancelott - Google Books, 2017

Table 2: Integrating Components in Andrew Campbell's Operating Model to the Current Study

Component	Description	Adopting to Clearpoint Residencies
Process	The key work activities and machinery needed for value creation and delivery process.	• Greywater collection, treatment, and reuse processes. • System maintenance and monitoring activities.

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Organization	The organizational structure, people who do the work and how they are organized.	● Roles and responsibilities within ClearPoint Residencies for water conservation system operation (e.g., building management, maintenance staff). ● Potential involvement of external service providers for system maintenance or water quality testing.
Location	Where is the work done, and what assets are required and available in these locations.	● Physical location of the greywater and rainwater harvesting systems (e.g., collection tanks, treatment plants). ● Availability of resources like water storage capacity, energy sources for treatment processes, etc.
Information	The information systems that support the work and value delivery.	● Data collection methods for water consumption, system performance, and maintenance records. ● Software used for monitoring and controlling the water conservation systems (if applicable).
Suppliers	The key partners who help in value creation and delivery.	● Suppliers of equipment or materials used in the greywater and rainwater harvesting systems. ● Companies providing maintenance services or water quality testing (if applicable).
Management System	Planning, budgeting, performance, risk management, continuous improvement and people management processes that the organization utilizes.	● Budgeting and cost allocation for water conservation system operation and maintenance. ● Performance metrics used to evaluate the effectiveness and efficiency of the systems (e.g., water savings, cost reduction). ● Risk management strategies to address potential issues like system malfunctions or water quality concerns. ● Continuous improvement processes for optimizing the water conservation system's performance.

Source: Campbell, 2017; Author, 2024

5. RESULTS AND DISCUSSION

The results revealed the adoption of components from Andrew Campbell's Operating Model in the grey water recycling system at Clearpoint Residencies. The components of Campbell's operating model related to the grey water recycling process at Clearpoint Residencies and the corresponding results are detailed below.

5.1 Process of Greywater Recycling

The grey water recycling process at Clearpoint Residencies, as illustrated in Figure 2, involves several key stages: collection, pre-treatment, treatment, filtration, storage, and distribution. These stages are systematically divided to ensure efficient recycling, starting with the collection of grey water, followed by its pre-treatment and treatment to remove contaminants. The water is then filtered, stored, and finally distributed for reuse within the facility.

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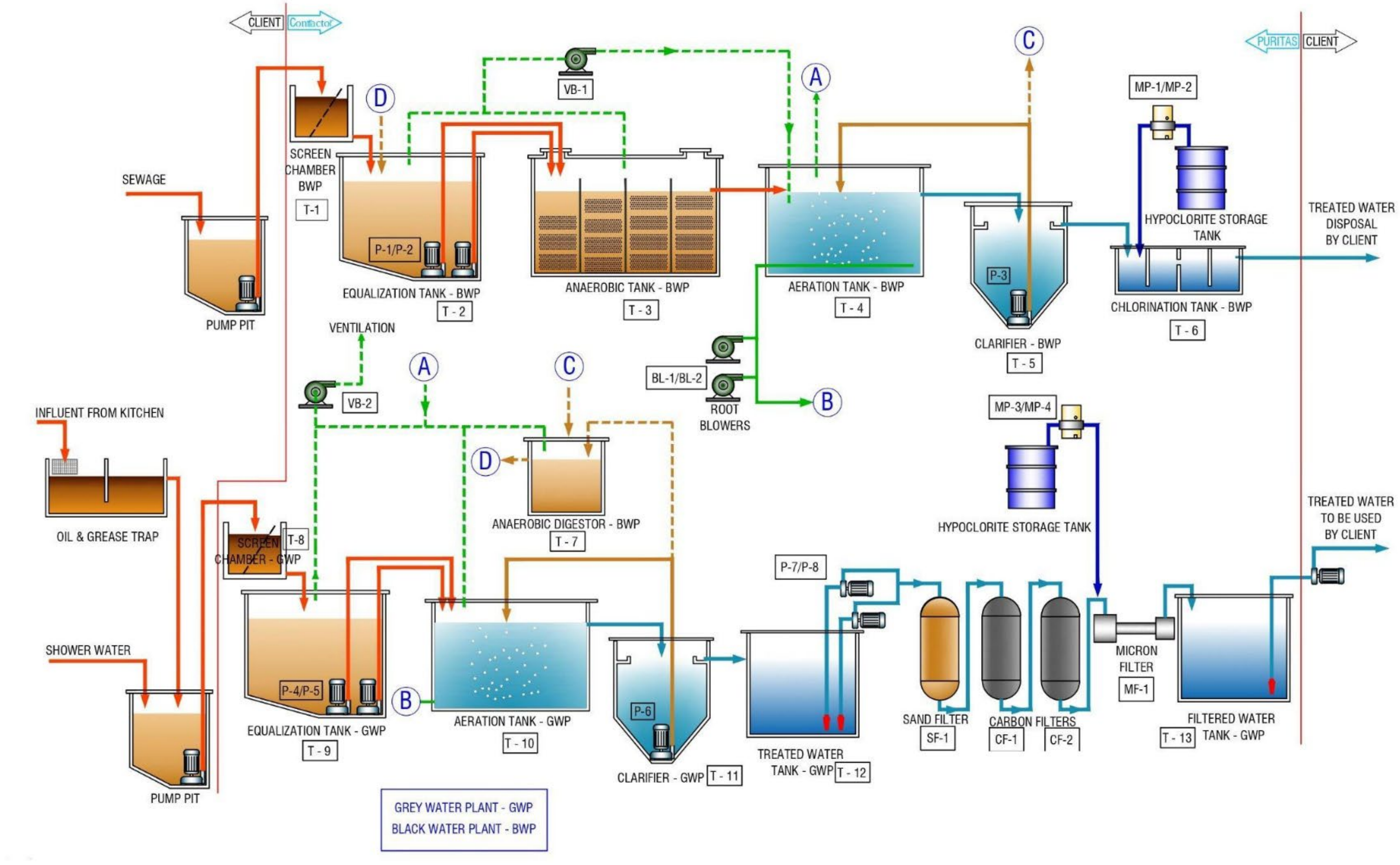
Figure 2: Grey Water Recycling Process

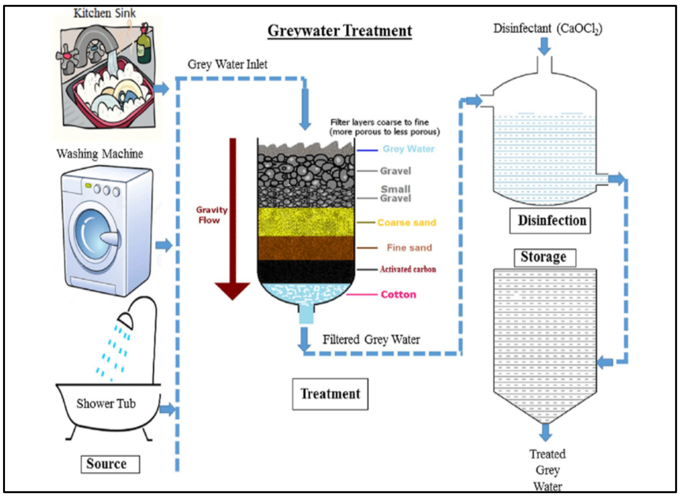


Source: Author, 2024

5.2 Collection of Greywater

Greywater recycling is a multi-step process, beginning with the collection of greywater (Samayamanthula et al., 2019). At Clearpoint Residencies, greywater is primarily collected from washrooms. This includes wastewater from showers, wash basins, laundry, and sewage. Figure 3 shows the sources of greywater collection. First move to the process line 1 in there they collected sewage water to the pump pit. A pump pit plays a crucial role in efficiently collecting and redistributing greywater for reuse. The pump pit typically houses a pump or pumps responsible for moving the greywater from various sources. In ClearPoint Residences First line pump pit collected sewage disposals to the pump pit.

Figure 3: Sources of Greywater Collection.



Source: Samayamanthula et al., 2019

5.3 Pre-treatment

When providing explanations on each key stage of the grey water recycling process, the first step of the treatment process for collected greywater can be identified as the pre-treatment stage which occurs at a dedicated plant. At this stage, debris and solids are removed to prepare the water for further treatment stages. The first tank (T-1) of the treatment process is screen chamber for the black water. The task of this T-1 as a screen chamber tank serves as an initial stage in the treatment process, specifically for the separation and removal of large solids and debris. Large solids, such as waste from toilets as black water.

In line 2 water collected from kitchen wastewater and shower water. Those kitchen disposal and shower water collected to the pump pit. Special thing is kitchen water coming from the oil and grease trap. The task of an oil and grease trap, also known as a grease interceptor or grease trap, is to capture and separate fats, oils, and grease (FOG) from wastewater before it enters the sewage system or treatment plant.

5.4 Treatment

As shown in Figure 2, the treatment process is divided into two process lines: Process Line 1 and Process Line 2.

i. Process Line 1- Black Water Plant

Next tank we can identify in this line 1 is Equalization tank (T-2). The equalization tank plays a vital role in the initial stages of treatment. As black water transitions from the screen chamber tank to the equalization tank, it undergoes essential preliminary processes. The primary task of the equalization

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tank is to balance the fluctuating flow and load of incoming black water, ensuring a smoother operation throughout the day. By storing excess wastewater during peak usage periods and gradually releasing it during lower flow periods, the tank effectively buffers against shock loads, such as heavy rainfall or intermittent discharges, preventing overwhelming downstream treatment processes. Additionally, by mixing black water with other wastewater streams like greywater or treated effluent, the tank promotes homogeneity in the wastewater composition, enhancing overall treatment efficiency. After the T-2 black water moves to the Anaerobic tank (T-3). The anaerobic tank in a black water treatment system plays a pivotal role in breaking down organic matter through anaerobic digestion, where microorganisms decompose waste in the absence of oxygen. This process transforms organic materials found in black water, such as feces and urine, into simpler compounds like methane, carbon dioxide, and water. Additionally, the anaerobic tank generates biogas, primarily methane, as a valuable byproduct. This biogas can be harnessed and utilized as a renewable energy source for various purposes, including heating and electricity generation, offering both environmental and economic benefits to the treatment process. The next tank is the Aeration tank (T-4). The aeration tank in a black water treatment system is instrumental in fostering aerobic biological processes essential for effective wastewater treatment.

By creating an oxygen-rich environment, the tank supports the growth and activity of aerobic bacteria, facilitating the breakdown of organic matter present in black water. This aerobic decomposition process is notably efficient in dismantling complex organic molecules, further enhancing the degradation of pollutants. Moreover, the aerobic bacteria actively consume organic matter as a food source, leading to a significant reduction in pollutants, particularly Biological Oxygen Demand (BOD). This reduction in BOD levels is crucial for enhancing water quality and alleviating the oxygen demand on receiving water bodies. Additionally, within the aeration tank, aerobic bacteria play a vital role in metabolizing ammonia, converting it into nitrites and nitrates through nitrification processes. After the T-4 black water moves to the clarifier (T-5). The task of clarifier in black water recycling settles suspended solids from treated wastewater, producing a clarified effluent. It separates sludge, which can be recycled or disposed of, improving water quality before further treatment or discharge. After undergoing the treatment processes, black water is transformed into treated water, which is then distributed for reuse.

ii. Line 2- Grey Water Plant

Moving to the treatment process, the sequence involves tanks including the Screen Chamber (T-8), Equalization Tank (T-9), and Aeration Tank (T-10). Tank 7 serves as a common tank for both line 1 and line 2, known as the Anaerobic Digester. Its task is to facilitate the decomposition of organic matter in wastewater without oxygen, a process known as anaerobic digestion. Microorganisms break down organic substances like sewage sludge or organic waste, resulting in the production of biogas, mainly methane, and stabilized organic residues. These tasks are pertinent to the black water treatment process. Subsequently, grey water proceeds to the Clarifier (T-11) before being transferred to the Treated Water Tank for storage.

5.5 Filtration

The treatment process, the next step is filtration, which involves two types of filters: sand filter and carbon filter. In grey water recycling, the sand filter's purpose is to eliminate suspended solids and fine particles from the grey water, leading to improved water clarity and decreased burden on subsequent treatment phases. Figure 4 shows the nature of the sand filter. Conversely, the carbon filter's role is to extract organic compounds, odors, and residual contaminants, thereby enhancing water quality for non-potable uses like irrigation or toilet flushing.

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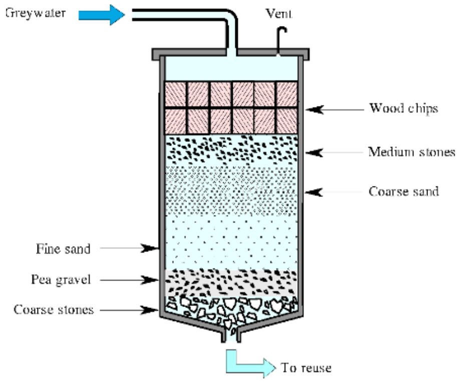
Figure 4: Sand Filter



Source: Ibrahim *et al.*, 2014

5.6 Storage and Distribution

Last tanks of the line 1, black water treatment are hypochlorite storage tank and Chlorination tank (T-6). The hypochlorite storage tank stores liquid hypochlorite solution, which is a commonly used disinfectant in water treatment. Its task is to safely store the hypochlorite solution until it is needed for disinfection purposes in the treatment process. The chlorination tank is where the hypochlorite solution stored in the hypochlorite storage tank is added to the treated water. The task of the chlorination tank is to ensure that the water is adequately disinfected, killing harmful bacteria, viruses, and other pathogens, before it is discharged or reused.

The primary uses of treated greywater do not include drinking, as particles, both beneficial and harmful, are removed during treatment. For instance, in the Maldives, desalination plants treat seawater to make it potable, which differs from greywater treatment. Instead, treated greywater is commonly employed for gardening purposes, especially in drip irrigation systems. This method efficiently delivers water directly to plant roots, minimizing waste and encouraging water conservation. At Clearpoint Residencies, the treated greywater is primarily utilized for gardening, servicing over 24,000 trees planted around the property via a drip irrigation system. This system delivers water efficiently to the trees, programmed for morning and evening irrigation cycles. Additionally, if rainwater harvesting proves insufficient, the property utilizes additional treated greywater for flushing purposes.

5.7 Organization Involvement to the Greywater Recycling

Initially, the installation of the treatment plant was outsourced to a specialized company, emphasizing the need for expertise in such endeavors. This underscores the reliance on professional experts who are familiar with the intricacies of such installations. Following installation, a structured approach to maintenance is crucial for the sustained functionality of the treatment plant. Responsibility for maintenance typically falls on the management corporation. Decisions regarding system upgrades and maintenance schedules are made collaboratively, with input from both the management corporation and the maintenance service providers. Clear guidelines and specifications are established, ensuring that maintenance tasks are carried out at specified intervals and in accordance with vendor guidelines. Additionally, maintenance agreements outline the responsibilities of the service provider, including adherence to operational schedules and warranty terms. This structured approach ensures accountability and clarity in the maintenance and operation of the treatment plant, ultimately contributing to the long-term sustainability of the infrastructure.

5.8 Location of the Greywater Recycling plant

When deciding on the location of the greywater collection tanks and treatment facilities within the building complex, the aim was to minimize pipeline length, reducing material and energy usage. Placing

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the facilities near the buildings enables gravity flow of wastewater into the treatment plant, eliminating excessive pumping equipment and energy consumption. Additionally, efforts were made to minimize disruption to the building's foundation and surrounding environment, situating the facilities approximately 10 meters away. This balance between proximity and operational efficiency considers potential odors from the treatment process, with measures like underground placement and odor management strategies to mitigate impacts on neighboring areas. Overall, the location selection prioritized efficiency, sustainability, and neighborly considerations to ensure effective and harmonious operation of the greywater treatment facilities. In terms of operation, space limitations and infrastructure considerations emerge as critical factors influencing functionality. While greywater systems typically require ample space, constrained space within the building complex presents challenges. Unlike projects with common space constraints, greywater treatment plant implementation requires sufficient land allocation, approximately 30 meters by 20 meters, to accommodate the infrastructure effectively.

5.9 Information Systems Related to Greywater Recycling

To monitor the performance of grey water systems, various tools and methods are employed. Typically, the treatment plant company conducts regular water quality tests to assess the efficacy of the treatment process, ensuring compliance with required standards for reuse or discharge. Additionally, visible panels offer a tangible way to visually gauge the system's performance, identifying potential issues or areas for improvement. Combining water quality tests, visual inspections, and integrated system indicators enables effective monitoring and evaluation of grey water systems. These tools ensure efficient operation and consistent achievement of treatment objectives. The table 3 refer the capacity of the water retaining structure, including grey water and treated water capacities.

Thorough assessments are crucial before implementing any treatment system to collect data on greywater volume, treatment efficiency, and reuse. Initially, facility examination determines factors like the number of toilets, occupancy levels, and daily usage rates, crucial for calculating treatment plant volume. Subsequently, specific treatment plans are selected based on these parameters to meet establishment requirements. The capacity of the plant, greywater volume, and reused water quantities are then determined accordingly as mentioned below.

Maximum Capacity of the plant (waste water m^3 per day) (Black water-37m^3/day + Grey water-101m^3/day)
Average discharged per day (Treated water per day m^3) (Treated water discharge-138m^3/day)

- Toilet Flushing – 37%(51m^3)
- Car Wash – 08% (11m^3)
- Gardening – 55% (76m^3)

Electricity usage – (Kw) (Installed power-12Kw)
Sludge free or amount of sludge generated per month (Nearly-9m^3 per year)

Table 3: Capacity of Water Retaining Structures

No.	Structure	Description	Capacity (m³)
01	**Overhead Water Tank**	Potable water	120.42
		Irrigation water	32.05
		Flush water	97.64
		Total	**250.11**
02	**Sump**	Gray water	309.43
		Rain water	177.1
		City water	407.35
		Total	**893.88**
03	**Cantilever Pool**	Pool ×10	317.1
		Balancing Tank ×10	67.3
		Total	**384.4**

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04	**Main Pool**	Pool ×10	215.43
		Balancing Tank ×10	21.54
		Total	**236.97**
05	**Kid Pool**	Pool	10.65
		Total	**10.65**
06	**Treatment Plant**	Anaerobic	26.4
		Anaerobic Digester	13.14
		Aeration	56.21
		EQ Tank	5.33
		Filtered Water	3.35
		Treated Water	7.56
		Oil Trap	5.22
		Total	**165.18**
		Grand Total Water Capacity	**1,941.19**

Source: Plumbing Detail Report Clearpoint Residencies.

Table 3 summarises the storage and treatment capacities that determine the scale of the greywater system, while below Table 4 presents the annual operating and maintenance (O&M) costs associated with maintaining this capacity and ensuring continuous, compliant operation.

5.10 Suppliers of Grey Water Treatment System

Supplies for the Grey water treatment system typically involve the procurement of equipment and materials from international sources, as local manufacturing may not be prevalent. The main contractor is responsible for overseeing the construction of all necessary structures to support the system's operation. However, the components themselves, such as treatment units and filtration systems, are often sourced from overseas suppliers to ensure quality and reliability.

5.11 Management System of Grey Water Recycling

The initial cost of the grey water system was Rs. 20 million in 2015. Then the costs associated with operating and maintaining the grey water system given below table 4.

Table 4: Costs Associated with Operating and Maintaining of the Grey Water.

Cost	**Amount (LKR)**
Maintenance agreement with Plumbing contractor (annum)	460,000.00
Chlorine and test kits (annum)	128,000.00
Skilled Labor - Technician – Rs. 60,000 x 12	120,000.00
Sludge removing – Rs. 10,500 x 12	126,000.00
Full deep cleaning – Rs. 97,000 x 12	1,164,000.00
Spates, Repairs and maintenance – Rs. 50,000 x 12	600,000.00
Other Cost – Smells and Neighbors concerns – Rs. 5,000 x 12	60,000.00
Total cost per annum	**2,658,000.00**
Filter replacements - carbon, sand & micro filters – Rs. 800,000/- every 5 years	800,000.00

Source: Plumbing Detail Report Clearpoint Residencies.

Addressing potential issues in the greywater system involves established procedures aimed at ensuring smooth functioning and addressing quantity concerns. Regular weekly checks monitor system operation, with any abnormalities indicated on the control panel. In case of issues, technical personnel, guided by maintenance engineers, promptly rectify the situation, maintaining system efficiency and reliability. Upgrades, once the system is operational, are deemed unnecessary unless specific requirements or advancements warrant them. While upgrades typically incur additional costs, certain

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enhancements, such as energy-efficient pumps or solar-powered systems, offer benefits like improved operational efficiency and reduced environmental impact. However, upgrades are carefully considered, prioritizing tangible benefits like enhanced energy efficiency or reduced maintenance requirements.

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5.12 Challenges of Implementing Grey Water Recycling System at Clearpoint Residencies

The case study of Clearpoint Residencies identified several challenges, including the selection of a suitable location for the water recycling system, operational difficulties, and issues with system functionality. These challenges were identified through interviews conducted during the investigation Similar implementation barriers such as space/location constraints, operational complexity, and ongoing monitoring needs are widely reported in building-scale greywater reuse projects (Niewitecka & Żubrowska-Sudoł, 2025; Van de Walle et al., 2023).

5.13 Selection of A Suitable Location

Identifying a suitable location for the greywater recycling plant initially presented a significant challenge. They faced the challenge of choosing criteria like distance from the main building and appropriate extent of the land. After find the land they face the challenge because it was a muddy land. Keep the stability they have to use the concrete bored pile in the stage of construction. The primary objective was to minimize disruption to neighboring residents while ensuring system effectiveness. Factors like land availability and proximity to the main building were carefully considered. After exploring alternative options, a plot of land adjacent to the main building was selected. However, this land had its challenges, notably its muddy terrain. Despite this hurdle, the team prepared the land by implementing measures to stabilize the ground and create a solid foundation for the plant installation. To mitigate potential inconvenience to residents, perimeter structures and boundary walls were employed to contain mild odors and minimize disruption to the community. Through strategic planning and effective implementation, the team successfully addressed the challenge of selecting a suitable location, contributing to sustainable water management at Clearpoint Residencies.

5.14 Operating The Water Recycling System

There are specific challenges associated with operating the water recycling system at Clearpoint Residencies. With a total of 153 apartments initially, though this number later reduced to 150 due to some residents merging units, ensuring efficient duct design becomes paramount. The challenge lies in configuring the ducts to accommodate the greywater recycling system effectively while minimizing the need for lengthy pipelines. Unlike traditional setups where connections are made to the city's sewer line, Clearpoint Residencies requires connections to the on-site treatment plant. This necessitates careful planning to optimize duct layout and minimize unnecessary pipeline usage. Consequently, the design of the ducts is crucial to facilitate the smooth flow of wastewater to the treatment plant while reducing material and energy usage associated with pipeline construction. By strategically planning the duct layout, Clearpoint Residencies aims to streamline its water recycling operations and enhance the overall efficiency of its sustainable water management infrastructure.

Operationally, building-scale greywater reuse requires careful plumbing/duct integration and

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efficient routing because long pipeline runs increase maintenance demand, energy use (pumping), and failure points (Niewitecka & Żubrowska-Sudoł, 2025; Van de Walle et al., 2023) Case-based research also notes that matching system design to occupancy patterns and demand points (e.g., toilet flushing and irrigation) is essential for reliable performance (Lanchipa-Ale et al., 2024).

5.15 System Function Issues

The established procedures are in place to address potential issues with the greywater recycling system at Clearpoint Residencies. Regular checks are conducted on a weekly basis to monitor the system's operation. During these checks, any abnormalities or malfunctions are indicated on the control panel itself, alerting maintenance personnel to potential issues. If a problem arises that the system cannot rectify on its own, technical personnel are deployed to address the issue promptly. These technical personnel, working under the guidance of maintenance engineers, are tasked with diagnosing and resolving any issues with the greywater recycling system. Their expertise ensures that any disruptions to the system's functionality are swiftly addressed, minimizing downtime and optimizing operational efficiency. By adhering to these established procedures, Clearpoint Residencies maintains the reliability and effectiveness of its greywater recycling infrastructure, ensuring sustainable water management practices in the long term.

The need for continuous monitoring and timely maintenance is consistent with recent evidence that greywater quality and system performance are variable and must be controlled through routine inspection, testing, and operational oversight (Budeli & Sibali, 2025; Mohan et al., 2024).

6. CONCLUSION

The implementation of greywater recycling at Clearpoint Residencies has yielded valuable insights for sustainable water management in urban settings. One crucial lesson is the importance of collaboration and expertise in project execution. Initially outsourcing the treatment plant installation to specialized companies underscores the need for technical proficiency in handling complex water systems, emphasizing the engagement of professional experts for successful implementation. This supports current practice-oriented literature that emphasises competent design, commissioning, and specialist oversight as key success factors for decentralised reuse systems in buildings (Niewitecka & Żubrowska-Sudoł, 2025)

Structured maintenance practices are another key lesson for sustained system functionality. Establishing clear guidelines and maintenance schedules, with defined responsibilities between the management corporation and service providers, ensures accountability and clarity in maintenance tasks, contributing to long-term infrastructure sustainability.

The location selection process emphasized prioritizing efficiency, sustainability, and neighborly considerations. Placing collection tanks and treatment facilities close to buildings minimizes pipeline length, reducing material and energy usage. Measures to mitigate odors and disruptions underscore the importance of community engagement and environmental sensitivity in infrastructure projects.

Looking ahead, the success of greywater recycling offers promising prospects for sustainable urban development. Scaling up initiatives to broader contexts can address water scarcity challenges on a larger scale. Replicating the model in other developments can significantly reduce freshwater demand and alleviate pressure on water resources, fostering resilient and water-secure urban communities while preserving the environment for future generations.

e-ISSN: 2229-8568

ACKNOWLEDGEMENT

The authors acknowledge the Centre for Real Estate Studies (CRES), Department of Estate Management and Valuation, University of Sri Jayewardenepura, Sri Lanka.

REFERENCES

1. Al-Jayyousi, O. R. (2003). Greywater reuse: towards sustainable water management. *Desalination*, 156 (1-3), 181-192 https://doi.org/10.1016/S0011-9164(03)00340-0

2. Allen, Lucy. (2010). Overview of greywater reuse: the potential of greywater systems to aid sustainable water management in Lucy Allen, Juliet Christian-Smith, Meena Palaniappan, *Overview of greywater reuse: the potential of greywater systems to aid sustainable water management.* California : Pacific Institute. ISBN 13: 978-1-893790-29-2

3. Asif, M., Searcy, C., Zutshi, A., & Fisscher, O. A. M. (2013). An integrated management systems approach to corporate social responsibility. *Journal of Cleaner Production*, *56*, 7–17. https://doi.org/10.1016/j.jclepro.2011.10.034

4. Budeli, P., & Sibali, L. L. (2025). Greywater Reuse: Contaminant Profile, Health Implications, and Sustainable Solutions. In *International Journal of Environmental Research and Public Health* (Vol. 22, Number 5). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/ijerph22050740

5. Friedler, E. (2004). Quality of individual domestic greywater streams and its implication for on-site treatment and reuse possibilities. *Environmental Technology*, *25*(9), 997–1008. https://doi.org/10.1080/09593330.2004.9619393

6. Ghaitidak, D. M., & Yadav, K. D. (2013). Characteristics and treatment of greywater-a review. In *Environmental Science and Pollution Research* (Vol. 20, Number 5, pp. 2795–2809). Springer Verlag. https://doi.org/10.1007/s11356-013-1533-0

7. Ghisi, E., & Freitas, D. A. (2024). Economic Feasibility of Rainwater Harvesting and Greywater Reuse in a Multifamily Building. *Water (Switzerland)*, 16(11). https://doi.org/10.3390/w16111580

8. Gross, A., Maimon, A., Alfiya, Y., & Friedler, E. (2015). *Greywater Reuse*. CRC Press. https://doi.org/10.1201/b18217

9. Hasan, Md. M., Shafiquzzaman, M., Nakajima, J., Ahmed, A. K. T., & Azam, M. S. (2015). Application of a Low Cost Ceramic Filter to a Membrane Bioreactor for Greywater Treatment. *Water Environment Research*, *87*(3), 233–241. https://doi.org/10.1002/J.1554-7531.2015.TB00141.X

10. Ibrahim, A., Alaziz, A., Naji, &., & Al-Saqer, F. (2014). The Reuse of Greywater Recycling For High Rise Buildings in Kuwait Country. In *Journal of Engineering Research and Applications* .4(3). 208-215

11. Isaksson, F., Herrmann, I., & Kvarnström, E. (2023). *Greywater reuse for different purposes in Sweden*. 978-91-8048-406-0 (electronic)

12. Karakhan, A. A. (2016). LEED-Certified Projects: Green or Sustainable? *Journal of Management in Engineering*, *32*(5). https://doi.org/10.1061/(ASCE)ME.1943-5479.0000451

13. Kordana-Obuch, S., Starzec, M., Wojtoń, M., & Słyś, D. (2023). Greywater as a Future Sustainable Energy and Water Source: Bibliometric Mapping of Current Knowledge and Strategies. In *Energies* 16(2), 934. https://doi.org/10.3390/en16020934

14. Lanchipa-Ale, T., Cruz-Baltuano, A., Molero-Yañez, N., Chucuya, S., Vera-Barrios, B., & Pino-Vargas, E. (2024). Assessment of Greywater Reuse in a University Building in a Hyper-Arid

Region: Quantity, Quality, and Social Acceptance. *Sustainability,* 16(7). https://doi.org/10.3390/su16073088

15. Madzaramba, T. H. (2024). Potential and acceptance of greywater for non-potable reuse at Zandspruit informal settlement in Johannesburg. *Cogent Engineering*, *11*(1). https://doi.org/10.1080/23311916.2024.2416726

16. Madzaramba, T. H., & Zanamwe, P. (2023). User perceptions and acceptance of treated greywater reuse in low-income communities: a narrative review. *Journal of Water and Climate Change*, *14*(11), 4236–4244. https://doi.org/10.2166/WCC.2023.414

Mekonnen, M. M., & Hoekstra, A. Y. (2016). Sustainability: Four billion people facing severe water scarcity. *Science Advances*, *2*(2), 1-6. https://doi.org/10.1126/sciadv.1500323

17. Mohan, S., Manthapuri, V., & Chitthaluri, S. (2024). Assessing factors influencing greywater characteristics around the world: a qualitative and quantitative approach with a short-review on greywater treatment technologies. *Discover Water*, *4*(1). https://doi.org/10.1007/s43832-024-00094-w

18. Niewitecka, K., & Żubrowska-Sudoł, M. (2025). Current Research Trends and Challenges Related to the Use of Greywater in Buildings. In *Water (Switzerland)* 17(23). https://doi.org/10.3390/w17233431

19. Operating Model Canvas - Andrew Campbell, Mikel Gutierrez , Mark Lancelott - Google Books. (2024). Retrieved August 12, 2024, from https://books.google.lk/books

20. Samayamanthula, D. R., Sabarathinam, C., & Bhandary, H. (2019). Treatment and effective utilization of greywater. *Applied Water Science*, *9*(4). https://doi.org/10.1007/s13201-019-0966-0

21. Van de Walle, A., Kim, M., Alam, M. K., Wang, X., Wu, D., Dash, S. R., Rabaey, K., & Kim, J. (2023). Greywater reuse as a key enabler for improving urban wastewater management. In *Environmental Science and Ecotechnology* (Vol. 16). Editorial Board, Research of Environmental Sciences. https://doi.org/10.1016/j.ese.2023.100277