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Greywater Reuse in Condominium Buildings: A Technical, Economic, and Environmental Analysis for Urban Sustainability

Reuso de Água Cinza em Condomínios Prediais: Uma Análise Técnica, Econômica e Ambiental para a Sustentabilidade Urbana

Reutilización de Aguas Grises en Construcción de Condominios: Un Análisis Técnico, Económico y Ambiental para la Sostenibilidad Urbana

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Abstract:
The rapid growth of urban areas and the consequent pressure on water resources make it necessary to adopt water conservation strategies in buildings. This article analyzes the potential for greywater reuse in residential buildings as a solution for reducing potable water consumption. The study focuses on the characterization of greywater, the available treatment technologies, and the feasibility of implementation in light of the ABNT NBR 16783:2019 standard. The methodology uses a systematic literature review and analysis of technical data on the efficiency of decentralized systems. The results indicate that the reuse of effluents from showers and sinks can reduce potable water demand by up to 40% in residential buildings, presenting economic viability with a variable return on investment time depending on the local tariff. It is stated that greywater reuse is an essential tool for sustainable water management, although it requires integrated projects and rigorous maintenance to ensure sanitary safety.

Keywords:
Water reuse. Greywater. Condominium buildings. Water sustainability. NBR 16783.

Resumo:
O crescimento rápido das áreas urbanas e a consequente pressão sobre os recursos hídricos tornam necessária a adoção de estratégias de conservação de água em edificações. Este artigo analisa o potencial de reuso de águas cinzas em condomínios prediais como uma solução para a redução do consumo de água potável. O estudo foca a caracterização das águas cinzas, as tecnologias de tratamento disponíveis e a viabilidade de implementação frente à norma ABNT NBR 16783:2019. A metodologia usa uma revisão bibliográfica sistemática e análise de dados técnicos de eficiência de sistemas descentralizados. Os resultados apontam que a reutilização de efluentes provenientes de chuveiros e lavatórios pode diminuir a demanda de água potável em até 40% em edifícios residenciais, apresentando viabilidade econômica com tempo de retorno de investimento variável conforme a tarifa local. Afirma-se que o reuso de águas cinzas é uma ferramenta essencial para a gestão hídrica sustentável, embora demande projetos integrados e manutenção rigorosa para garantir a segurança sanitária.

Palavras-chave:
Reuso de água. Águas cinzas. Condomínios prediais. Sustentabilidade hídrica. NBR 16783.

Resumen:
El rápido crecimiento de las áreas urbanas y la consiguiente presión sobre los recursos hídricos hacen necesario adoptar estrategias de conservación del agua en los edificios. Este artículo analiza el potencial de la reutilización de aguas grises en condominios como solución para reducir el consumo de agua potable. El estudio se centra en la caracterización de las aguas

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grises, las tecnologías de tratamiento disponibles y la viabilidad de implementación en relación a la norma ABNT NBR 16783:2019. La metodología utiliza una revisión sistemática de la literatura y un análisis de datos técnicos sobre la eficiencia de los sistemas descentralizados. Los resultados indican que la reutilización de efluentes de duchas y lavabos puede reducir la demanda de agua potable hasta en un 40% en edificios residenciales, presentando viabilidad económica con un retorno de la inversión en el tiempo que varía dependiendo de la tarifa local. Se afirma que la reutilización de aguas grises es una herramienta esencial para la gestión sostenible del agua, aunque requiere proyectos integrados y un mantenimiento riguroso para garantizar la seguridad sanitaria.

Palabras clave:
Reutilización del agua. Aguas grises. Construcción de condominios. Sostenibilidad del agua. NBR 16783.

1. Introduction

The water crisis and the growing demand for treated water in large urban centers have driven the search for complementary alternatives for water supply and conservation. In Brazil, the construction sector has sought to incorporate sustainable solutions into new developments, focusing not only on environmental preservation but also on reducing operational costs for condominium owners. Among the most promising approaches is the reuse of greywater.

The composition of greywater can vary depending on: * user habits; * type of building; * cleaning products used.

Greywater is defined as non-industrial domestic wastewater, free from contributions from toilets and kitchen sinks, originating from showers, washbasins, bathtubs, and washing machines. In residential buildings, where population density per projected area is excessive and the volume of greywater generated is considerable, it represents a strategic opportunity to close the local hydrological cycle.

This article aims to detail the technical and regulatory aspects of greywater reuse in multi-family residential buildings. It will address the required quality parameters, the essential treatment steps, and the economic and environmental impacts of adopting these systems. The importance of this study lies in the need to disseminate technical knowledge to assist designers and condominium managers in making decisions about implementing greywater reuse systems.

2. Theoretical Framework

2.1. Concept and Classification of Greywater

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According to ABNT NBR 16783:2019, wastewater from a building can be classified according to its origin and pollutant load. Greywater is subdivided into "clear" and "dark." Light greywater is that resulting from showers and sinks, having a lower concentration of organic matter and suspended solids. Dark greywater includes effluents from washing machines and tanks, which may contain a higher load of surfactants and chemical residues. "Segregation at the source is the fundamental principle for the efficiency of reuse systems, allowing effluents with lower contamination potential to be treated with less expensive processes." (HESPANHOL, 2015).

2.2. The Regulatory Context: NBR 16783:2019

The publication of NBR 16783 defines rigorous parameters for the use of alternative sources of non-potable water in buildings. The standard establishes procedures for the characterization, sizing, operation, and maintenance of the systems. A central focus of the standard is ensuring sanitary safety, preventing direct connection between the potable water network and the reuse network.

Table 1. Quality parameters for reuse water no Drinkable .

Parameter	Limit Value (NBR 16783)
pH	6.0 to 9.0
Turbidity	≤ 5 UNT
Coliforms Thermotolerant	< 200 MPN/100mL
Free Residual Chlorine	0.5 to 5.0 mg/L
Apparent Color	≤ 15 uH

Source: Adapted from ABNT (2019). Data compiled for academic purposes.

2.3. Treatment Technologies

Greywater treatment processes in residential buildings range from simple physical processes to advanced biological processes. Due to space constraints in urban areas, compact systems are preferred.

1. Physical Processes: Sand filtration, ultrafiltration membranes, and disinfection (chlorination or UV).
2. Biological Processes: Activated sludge reactors, moving bed bioreactors (MBBR) and membrane bioreactors (MBR).

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3. Hybrid Systems: Combine sedimentation, filtration, and advanced oxidation to ensure the removal of emerging contaminants and odors.

3. Methodology

This article is characterized as a descriptive and exploratory study, based on a systematic bibliographic review of technical and scientific literature published between 2010 and 2025. Data collection was carried out in databases such as Google Scholar, SciELO, and CAPES journals, using the descriptors "greywater reuse," "buildings," and "urban sustainability." Scientific works and technical documents relevant to the topic were selected, prioritizing studies that presented quantitative results on the technical and economic performance of the systems.

For the technical feasibility study, efficiency data from different treatment technologies described in national case studies were gathered. The economic analysis considered the average implementation cost in new projects compared to the savings generated in water and sewage bills, using the average rates of Brazilian capitals as a reference.

The inclusion criteria for the sources were: * Alignment with current Brazilian legislation; * Focus on multi-family buildings (condominium buildings); * Quantitative data on water savings and quality of treated effluent.

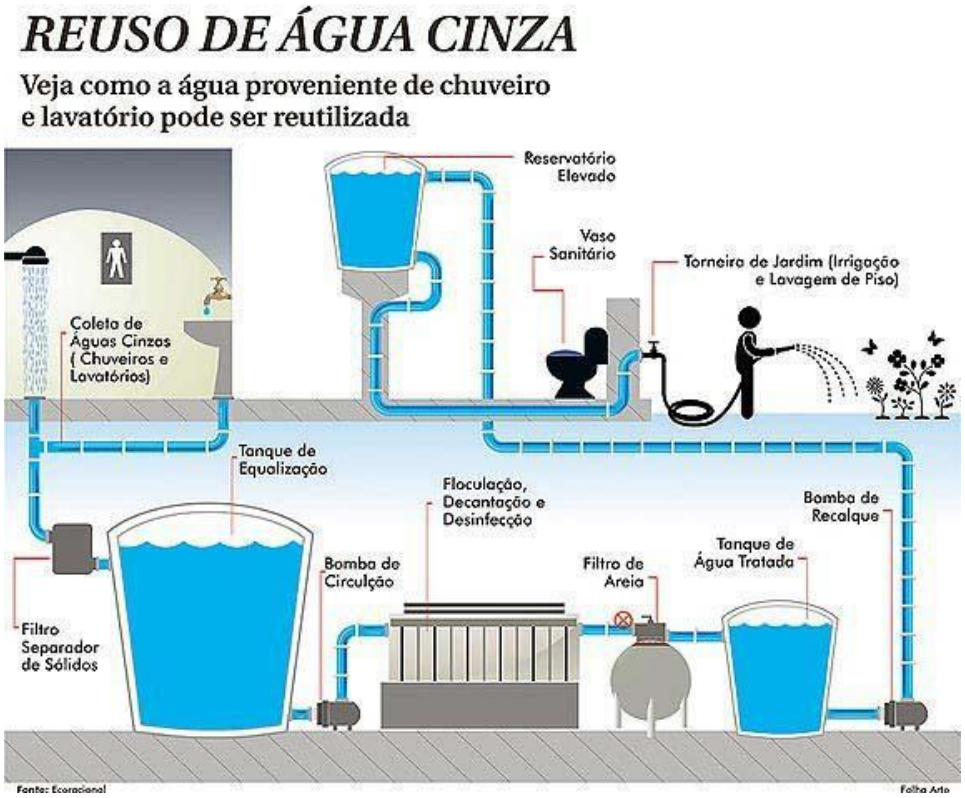
4. DISCUSSION

4.1. Water Saving Capacity

In a typical apartment building, the demand for water for non-potable uses (toilets, floor washing, and irrigation) represents about 30% to 50% of total consumption. Since the generation of greywater (shower and sink) is usually greater than this demand, the system becomes self-sufficient for these uses.

Figure 1: Schematic of a Reuse System in Buildings

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Source: Reproduction authorized for educational purposes (Acquacontroll , 2024).

The diagram above explains the segregation of greywater at the source, the centralized treatment on the ground floor or basement, and the redistribution to non-potable consumption points through a dedicated network.

4.2. Challenges for application in Existing Buildings (Retrofitting)

The biggest obstacle to greywater reuse in existing apartment buildings is the need for a double piping network. In new projects, the additional cost is marginal (estimated at 1% to 2% of the total construction cost), but in renovations, the cost of breaking masonry and installing new distribution columns can make the project financially unfeasible in the short term.

4.3. Economic Feasibility Analysis

The payback period also depends on: * implementation cost; * condominium consumption; * local tariff; * operation and maintenance costs.

5. Conclusion

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Greywater reuse in residential buildings is establishing itself as one of the most effective strategies for conserving water resources on an urban scale. Technical analysis has proven that current technologies are capable of producing reclaimed water with quality exceeding the limits required by NBR 16783, ensuring safety for users.

The main conclusions of this study indicate that: 1. Viability is maximized when the system is integrated from the architectural design phase. 2. Saving potable water generates a direct positive impact on the condominium's cash flow. 3. Preventive maintenance is the critical factor in avoiding odors and the proliferation of pathogens in the distribution system.

It is suggested that public incentive policies, such as property tax discounts for sustainable buildings, be intensified to accelerate the acceptance of these technologies, contributing to the resilience of cities in the face of future water crises.

6. Technical specifications of treatment systems

6.1. Qualitative characterization of greywater

For the correct sizing of a Greywater Treatment Plant (GTP) in residential buildings, it is essential to understand the variability of the pollutant load. Studies indicate that the Biochemical Oxygen Demand (BOD) of light greywater varies between 150 and 300 mg/L, while turbidity can fluctuate significantly depending on the use of personal hygiene products.

Table 2. Input parameters and efficiency targets in ETACs.

Parameter	Water Raw Ash (Medium)	Water Treated (Goal)	Efficiency Expected
BOD5 (mg/L)	250	< 10	96%
COD (mg/L)	450	< 30	93%
Solids Suspended (mg/L)	150	< 5	97%
Surfactants (mg/L)	15	< 1	93%

Source: Compilation of Brazilian case studies (2020-2024).

6.2. Sizing of the Storage Tank

In residential buildings, physical space is a limited resource. The raw greywater storage tank must be sized to prevent stagnation for periods exceeding 24 hours, which could

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lead to anaerobic processes and the generation of unpleasant odors (hydrogen sulfide gas). The use of preliminary ventilation in the equalization tank is a recommended practice to keep the effluent fresh before biological treatment.

6.3. The Role of Membrane Bioreactors (MBRs)

MBR technology has become prominent in high-end condominiums. It combines the activated sludge process with physical separation using ultrafiltration or microfiltration membranes.

- Advantages of MBR:
  - High effluent quality: Removal of viruses and bacteria without excessive need for chemical disinfectants.
  - Compactness: It occupies up to 50% less space than conventional settling systems.
  - Automation: Enables remote monitoring of water quality.
  -

7. Socioeconomic and environmental impacts

7.1. Reducing the water footprint

Reusing water in a 100-apartment building (averaging 3.5 people per unit) can save approximately 4.5 million liters of potable water annually. This volume is equivalent to supplying approximately 25 Brazilian families for the same period.

7.2. Real Estate Recognition and Certifications

Buildings that adopt greywater reuse are eligible to obtain environmental certifications such as LEED (Leadership in Energy and Environmental Design) or the AQUA-HQE seal. In the Brazilian market, properties with these certifications show a resale value 10% to 15% higher than conventional properties, in addition to a significantly faster sale rate.

7.3. Psychological Points and the "Disgust Factor"

Despite the advantages, acceptance by residents is crucial. Reused water must be colorless and odorless. The presence of any discoloration in the toilet bowl can generate com-

plaints and resistance to the system. Therefore, final polishing with activated carbon or advanced oxidation systems (such as ozone) is frequently employed to ensure the aesthetic quality of the water.

8. Guidelines for operation and maintenance (O&M)

Imperfections in maintenance are the main cause of shutdowns of reuse systems in condominiums. O&M guidelines should include: * Filter Cleaning: Weekly or bi-weekly, depending on the solids load. * Sensor Calibration: Monthly for pH and residual chlorine sensors. * Laboratory Analyses: As required by local legislation (usually quarterly or semi-annually) to validate the effectiveness of the treatment with environmental and health agencies.

9. Final considerations on the fate of reuse

Greywater reuse will cease to be a "green" option and become a structural necessity. With the intensification of water crises and the real increase in the cost of treated water, the partial water independence of residential buildings will be a sought-after differentiator and a safety measure for cities. The development of treatment technologies and the consolidation of regulations in Brazil point towards a scenario where reuse will be standard in all new medium and large-scale constructions.

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