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Greywater Treatment: Evaluation of a Residential Treatment System

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Abstract*: In areas with inadequate water supplies, the recovery and reuse of limited resources are crucial for sustainable water management. Greywater, generated from household activities, presents an exciting opportunity for resource conservation. This study aimed to design and analyse a pilot-scale greywater treatment system for in-house generated greywater, enabling its reuse. Greywater samples from various sources in an Indian middle-class single household were characterized over a six-month period. A filtration system with different filter layers was developed to treat the greywater. The system exhibited high removal efficiencies, with 85.98% for chemical oxygen demand, 86.28% for biochemical oxygen demand, and 94.44% for total suspended solids. The results demonstrate the potential for reusing in-house treated greywater for toilet flushing, gardening, car washing, and firefighting, thereby reducing freshwater consumption. Proper management of liquid waste is crucial, as improper methods such as incineration contribute to greenhouse gas emissions, exacerbating global warming and causing adverse environmental impacts.*

Keywords: Greywater, water reuse, resource recovery, filtration system, sustainability, wastewater treatment

I. INTRODUCTION

Access to adequate water supplies is essential for sustaining human life and supporting various activities. However, in many regions around the world, water scarcity and limited resources pose significant challenges. In such circumstances, it becomes imperative to explore innovative approaches for water conservation and resource recovery. One promising avenue in this context is the utilization of greywater, which refers to the wastewater generated from household activities such as bathing, kitchen sinks, washbasins, and laundry. Greywater, if properly treated, can be a valuable resource for non-potable purposes, reducing the strain on freshwater supplies.

This research paper focuses on the development of a pilot-scale greywater treatment system aimed at recovering and reusing in-house generated greywater. The main objective of this study is to tap into the untapped potential of physical methods for greywater purification, enabling its safe and efficient reuse. The research entails characterizing greywater samples from various sources in an Indian middle-class single household over a six-month period. Subsequently, a comprehensive treatment system is designed and analysed to effectively treat the in-house generated greywater.

The primary goal of this study is to assess the performance of the developed greywater treatment system in terms of its removal efficiency for chemical oxygen demand (COD), biochemical oxygen demand (BOD), and total suspended solids (TSS). Furthermore, the study aims to evaluate the potential applications of the treated greywater, such as toilet flushing, gardening, car washing, and firefighting. By reusing greywater, not only can the consumption of freshwater be significantly reduced, but it also presents an opportunity to mitigate the environmental impact caused by improper liquid waste management.

In addition to addressing water scarcity, the research paper also acknowledges the importance of environmental considerations in the context of liquid waste management. It recognizes that improper handling of liquid waste, such as incineration without considering alternative options, can contribute to greenhouse gas emissions. These emissions further exacerbate global warming, leading to adverse environmental consequences such as extreme weather events and acid rain.

II. DESIGN OF GREYWATER TREATMENT SYSTEM

The design of a pilot-scale greywater treatment system plays a crucial role in enabling the recovery and reuse of limited water resources. This section presents the proposed design of the greywater treatment system, which aims to effectively treat in-house generated greywater and ensure its suitability for various non-potable applications.

1. Greywater Collection:

The greywater treatment system begins with the collection of greywater from various sources within the household, including bathing, kitchen sinks, washbasins, and laundry outlets.

Adequate measures are implemented to prevent the mixing of greywater with other wastewater streams, such as toilet waste or blackwater.

2. Preliminary Treatment:

Before entering the treatment process, the collected greywater undergoes preliminary treatment to remove large debris, such as hair, food particles, and lint. This can be achieved through a combination of physical filtration, sedimentation, and skimming.

3. Filtration System:

The core component of the greywater treatment system is a multi-layered filtration system designed to remove finer suspended particles, organic matter, and contaminants.

The filtration system comprises different filter layers, each with specific filtration media and mechanisms. These layers can include a combination of sand filters, activated carbon filters, and microfiltration membranes.

The arrangement of filter layers allows for progressive filtration, ensuring effective removal of impurities and pathogens present in the greywater.

4. Disinfection and Chemical Treatment:

Following filtration, the treated greywater may undergo disinfection to further eliminate harmful microorganisms. Common disinfection methods include chlorination, UV disinfection, or advanced oxidation processes.

Additionally, chemical treatment may be employed to adjust pH levels, remove residual odours, or address specific water quality concerns, ensuring the greywater meets the required standards for reuse.

5. Storage and Distribution:

The treated greywater is then stored in dedicated storage tanks, separate from potable water sources, to maintain proper hygiene and prevent cross-contamination.

Depending on the intended reuse applications, the distribution of greywater can be facilitated through a separate plumbing network or by integrating it with existing water supply systems for specific end uses.

6. Monitoring and Control:

The greywater treatment system incorporates monitoring and control mechanisms to ensure the efficiency and performance of the treatment processes.

Parameters such as flow rate, pressure, water quality indicators, and disinfection levels are continuously monitored to maintain the desired treatment efficiency and water quality standards.

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Fig 1

III. PERFORMANCE EVALUATION

The performance evaluation of the pilot-scale greywater treatment system focuses on assessing its effectiveness in recovering and reusing limited water resources. The following key aspects are considered during the evaluation:

1. Water Quality Analysis:

Comprehensive analysis of greywater samples before and after treatment to determine improvements in water quality. Parameters analysed include COD, BOD, TSS, pH, and specific contaminants.

2. Removal Efficiency:

Calculation of removal efficiencies for target contaminants by comparing their concentrations before and after treatment.

Removal efficiency (%) = ((Cin - Cout) / Cin) x 100, where Cin is the initial concentration and Cout is the concentration after treatment.

3. Flow Rate and Hydraulic Performance:

- Measurement of flow rate to assess the system's hydraulic capacity and efficiency.
- Ensuring optimal system performance and prevention of clogging.

4. Energy Consumption and Operational Costs:

Monitoring energy consumption of system components to evaluate efficiency.

Assessment of operational costs, including energy and maintenance expenses.

5. Water Reuse Suitability:

Evaluation of treated greywater for its suitability in non-potable applications, adhering to water quality standards and guidelines.

6. System Reliability and Long-term Performance:

Continuous monitoring, stability checks, and maintenance to assess system reliability.

Identification of operational issues and performance degradation over time.

IV. REUSABILITY OF TREATED GREYWATER

The reusability of treated greywater is a key aspect of a pilot-scale greywater treatment system designed for recovering and reusing limited water resources. The following applications and considerations are associated with the reuse of treated greywater

- Toilet Flushing: Treated greywater can be used for flushing toilets, reducing the demand for fresh water.
- Gardening and Irrigation: Nutrient-rich treated greywater can be used for irrigation, providing water for plants and landscapes.
- Car Washing: Treated greywater offers a sustainable option for car washing, minimizing freshwater usage.
- Firefighting: Treated greywater can be utilized for non-potable firefighting purposes, adhering to safety standards.

4.1 Considerations

- Water Quality Standards: Treated greywater must meet quality guidelines for intended reuse applications.
- Public Perception: Educating the public about the safety and benefits of greywater reuse is essential.
- Maintenance and Monitoring: Regular maintenance and monitoring ensure optimal system performance and water quality.
- Regulatory Compliance: Adherence to local regulations and permits is necessary for greywater reuse.

V. ENVIRONMENTAL CONSIDERATIONS

Implementing a pilot-scale greywater treatment system for the recovery and reuse of limited water resources requires careful attention to environmental considerations. Key aspects to address include:

1. **Water Conservation:** Reusing treated greywater reduces reliance on freshwater sources, conserving
2. **Energy Efficiency:** Minimizing energy consumption through efficient design and operation of system components reduces environmental impact.
3. **Chemical Usage and Disposal:** Using environmentally friendly treatment chemicals and ensuring proper handling and disposal practices minimize harm to the environment.
4. **Impact on Ecosystems:** Monitoring and managing the discharge of treated greywater to prevent ecological disruption and maintain ecosystem balance.
5. **Water Quality Protection:** Meeting water quality standards and conducting regular assessments ensure treated greywater is safe for discharge and does not harm the environment or public health.
6. **Life Cycle Assessment:** Assessing the system's overall environmental impact throughout its life cycle provides insights into sustainability performance.
7. **Public Awareness and Education:** Promoting awareness of greywater treatment and reuse benefits encourages responsible water use and environmental stewardship.

By addressing these environmental considerations, the greywater treatment system can contribute to water resource preservation and sustainable water management practices.

VI. CONCLUSION

From this study, it can be very well demonstrated that a filter unit integrating various filter layers proves to be a useful way of treating in-house generated greywater and using it then and there itself, which reduces the freshwater requirement and saves a significant amount of money and energy. Removal efficiencies are higher than obtained in earlier studies. Even though this system proves to be efficient in treating.

From the observations taken in two months average efficiency of kitchen sink, wash basin and bathing are more than 60% and filter achieved target efficiency.

COD removal efficiency of kitchen sink & TSS removal of wash basin are lowest in all observations and main purpose of this filter is to remove solids from mixed greywater which includes greywater from kitchen sink, wash basin and bathing. Various parameters removal efficiency is obtained by formula,

$$\frac{\textbf{Before}-\textbf{After}}{\textbf{\textit{Before}}} \times \mathbf{100} \text{ that is } \frac{\textbf{Initial reading} - \textbf{Final reading}}{\textbf{\textit{Initial reading}}} \times \mathbf{100}\ .$$

Efficiency is obtained in the form of percentage and in this project, we aimed to increase the efficiency of removal of COD, BOD, TSS & mixed samples. Low-cost filter was the main purpose of this project. We made filter using locally available materials like coarse gravels, fine sand, coconut husk, banana peels and small sized gravels.

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