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REVIEW PAPER ON "VERTICAL TRICKLING SUMP FILTERS FOR GREY WATER RETRIEVAL"

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Abstract - This study presents the design and analysis of a low-cost greywater treatment system using a vertical trickling sump filter integrated with a multi-media filtration unit and biological aeration process.Greywater, which constitutes approximately 50–80% of domestic wastewater, represents a significant alternative water resource if properly treated. However, the direct discharge of untreated greywater contributes to environmental pollution and increases pressure on limited freshwater resources. The results demonstrate a significant reduction in pollutant levels, indicating the effectiveness of the combined filtration and biological treatment processes. The system operates under gravity flow, ensuring low energy consumption and minimal operational complexity. Greywater samples collected from domestic sources are analyzed before and after treatment to evaluate system performance. Key water quality parameters such as pH, turbidity, total dissolved solids (TDS), biochemical oxygen demand (BOD), and chemical oxygen demand (COD) are assessed. Overall, the study highlights that the developed system is cost- effective, easy to operate, and environmentally sustainable. It provides a practical approach to greywater reuse, contributing to water conservation, reduced environmental impact, and improved wastewater management practices in developing regions.
KeyWords: Greywater Treatment, Multi-media Filtration, Wastewater Reuse, BOD, COD.

1. INTRODUCTION

Water is an essential natural resource for human survival and sustainable development. However, rapid urbanization, population growth, and increased domestic water consumption have led to significant pressure on available freshwater resources. In many developing countries, including India, water scarcity has become a major concern, making efficient water management and reuse practices increasingly important.Domestic wastewater is broadly classified into blackwater and greywater. Greywater, which originates from sources such as bathrooms, sinks, laundry, and kitchen activities (excluding toilet waste), accounts for nearly 50–80% of total household wastewater. Compared to blackwater, greywater contains fewer pathogens and lower levels of contamination, making it relatively easier to treat and reuse for non-potable purposes such as irrigation, toilet flushing, and cleaning.

Despite its potential, untreated greywater is often discharged directly into the environment, contributing to pollution of water bodies and soil degradation. Conventional wastewater treatment methods, including advanced filtration and chemical processes, are often expensive, energy-intensive, and require technical expertise, making them unsuitable for small-scale or household-level applications.

To address these challenges, there is a growing need for low-cost, efficient, and decentralized greywater treatment systems. In this context, the present study focuses on the design and analysis of a vertical trickling sump filter integrated with a multi-media filtration system and biological aeration. The system utilizes easily available materials such as gravel, sand, and activated charcoal to remove physical and chemical impurities, while biological aeration enhances the breakdown of organic pollutants.

The proposed system aims to provide an economical, eco- friendly, and easy-to-operate solution for greywater treatment. By improving water quality and enabling safe reuse, this approach contributes to water conservation, reduces environmental pollution, and promotes sustainable water management practices.

2. LITERATURE REVIEW

Greywater treatment and reuse have gained significant attention in recent years due to increasing water scarcity and the need for sustainable water management practices. Several researchers have explored different treatment techniques ranging from simple filtration systems to advanced biological and chemical processes.

Characteristics. This section presents a comprehensive review of the existing literature systems, emphasizing performance assessment, optimization strategies, and comparative studies across diverse configurations.

A. Filtration System Efficiency for Greywater Treatment

Anna Tusiime et al. (2022) evaluated a laboratory-scale filtration system using sand and granular activated carbon. The study analyzed physico-chemical and microbiological parameters and found that treatment efficiency improved with increased hydraulic retentiontime. Pollutant removal ranged from 60.8% to 100% for parameters such as turbidity, BOD, COD, and microbial content. The study also showed a high acceptance rate of treated greywater for reuse in non-potable applications.They demonstrated that MBBR systems could maintain high biomass concentration while allowing compact reactor design.

B. Comparison of Greywater Treatment Technologies

Vandana Singh et al. (2018) reviewed various greywater treatment techniques, including physical, chemical, biological, and constructed wetlands. Their findings indicated that simpler methods like physical filtration and constructed wetlands are more economical and suitable for water-scarce regions. The study emphasized the need for balancing efficiency, cost, and feasibility.

C. Nitrogen Removal and Nitrification–Denitrification Studies

Helness and Odegaard (1999) focused on nitrification performance in aerobic MBBR systems. Their research demonstrated ammonia removal efficiencies above 90% at moderate dissolved oxygen concentrations. They attributed this performance to the stratified structure of biofilms, which supports nitrifying bacteria in aerobic zones.

Rusten et al. (2006) investigated simultaneous nitrification and denitrification (SND) in single-stage MBBR systems. Their findings showed that oxygen gradients within the biofilm allowed partial denitrification even under fully aerated conditions. This work significantly contributed to reducing reactor complexity in nutrient removal applications.

Odegaard (2006) reviewed nitrogen removal mechanisms in MBBR systems and highlighted the advantages of multi-stage reactor configurations. He reported that staged anoxic–aerobic MBBR systems could achieve total nitrogen removal efficiencies exceeding 80%.

D. Review of Greywater Recycling Techniques

Prashanna Rangan and K. Heenalisha (2019) analyzed different greywater recycling approaches and highlighted that greywater, due to its lower organic load and absence
of fecal matter, is easier to treat. The treated water can be effectively reused for irrigation, flushing, and other domestic purposes. The study also emphasized that proper treatment reduces environmental pollution and helps in conserving freshwater resources. Additionally, it was noted that selecting an appropriate treatment method depends on the quality and source of greywater.

E. Low-Cost Filtration System for Domestic Use

Shobha Kundu et al. (2015) conducted a laboratory-scale study using a natural filtration system consisting of sand, aggregates, and other materials. The results showed improvement in parameters such as turbidity, dissolved oxygen, and total dissolved solids, proving the effectiveness of low-cost treatment systems for small-scale applications. The study also highlighted that such systems require minimal maintenance and can be easily implemented in households, schools, and small communities.

Bassin et al. (2011) compared and Integrated Fixed-Film Activated Sludge (IFAS) systems under similar operating conditions. They reported that IFAS systems provided higher volumetric loading capacity and improved nitrification rates, making them suitable for upgrading existing wastewater treatment plants.

Chen et al. (2013) evaluated different carrier filling ratios and reactor configurations and concluded that optimal performance is achieved when carrier filling is maintained between 50% and 70%.

F. Need for Alternative Water Resources in India

R. T. Pachkor and D. K. Parbat (2017) highlighted the growing water crisis in India due to rapid urbanization and industrialization. The study emphasized the importance of adopting alternative water sources such as greywater reuse, rainwater harvesting, and wastewater recycling. It also pointed out that efficient water management strategies are essential to meet future water demand and reduce stress on existing freshwater resources.

G Decentralized Treatment Methods and Cost- Effectiveness

Kazi Faraz Ahmed Abdullah et al. (2022) discussed decentralized greywater treatment methods such as septic tanks, constructed wetlands, and sand filtration systems. These methods were found to be cost-effective, easy to operate, and suitable for small communities and rural areas. The study further emphasized that decentralized systems reduce the burden on centralized wastewater treatment plants and promote sustainable water reuse practices.

H. Characteristics and Variability of Greywater

Peter L. M. Veneman and Bonnie Stewart (2002) studied the characteristics of greywater from different sources. The results showed variation in parameters such as BOD, TSS, and nitrogen content, highlighting the need for adaptable treatment systems.

The study also indicated that greywater quality is influenced by household activities, detergents, and usage patterns, which must be considered during system design.

I. Biological Treatment Suitability for Greywater

B. Jefferson et al. (2004) concluded that biological treatment processes are most suitable for greywater due to its biodegradable nature. However, they also noted challenges such as high COD/BOD ratio and variability in water composition. The study suggested that combining biological treatment with physical filtration can improve overall efficiency. ANN–fuzzy models for predicting treatment performanceunder dynamic operating conditions.

J. Integrated Biological and Filtration Treatment Systems

Noah I Galil (2005) developed a pilot-scale system combining biological treatment with sand filtration and disinfection. The system achieved high removal efficiencies, including 82% for TSS, 98% for turbidity, and 96% for BOD, demonstrating the effectiveness of combined treatment methods. The study also highlighted that integrated systems produce better effluent quality compared to single-stage treatment processes.

3. DESIGN ASPECTS AND OPERATIONAL PARAMETERS OF VERTICAL TRICKLING SUMP FILTER

Overview of Vertical Trickling Filter System

The Vertical Trickling Sump Filter is a low-cost and efficient greywater treatment system that combines physical filtration and biological treatment processes. In this system, greywater flows vertically through multiple layers of filter media such as gravel, sand, activated charcoal, and other locally available materials. These layers remove suspended solids, organic matter, and impurities through filtration, adsorption, and microbial activity.

Unlike conventional wastewater treatment systems, this method operates mainly under gravity flow, reducing energy requirements and operational costs. The presence of a biological aeration unit enhances the degradation of organic pollutants by promoting the growth of aerobic microorganisms. This makes the system suitable for small-scale domestic and decentralized applications, especially in water-scarce regions.

Classification of Greywater Treatment System Configurations

Greywater treatment systems can be classified based on their design and treatment approach:

1 **Single Stage Filtration Systems**

These systems consist of a single filtration unit where greywater passes through layered media for removal of suspended solids and basic impurities. They are simple, economical, and suitable for low-strength wastewater.

2 **Multi-stage Filtration Systems**

Multi-stage systems include pre-treatment, filtration, and post-treatment units. Each stage is designed to remove specific contaminants, resulting in higher treatment efficiency and better water quality.

3 **Integrated Filtration and Biological Systems**

These systems combine physical filtration with biological treatment processes such as aeration. The integration improves removal of organic pollutants (BOD, COD) and enhances overall system performance.**Filter Media Characteristics**

Filter media play a crucial role in determining treatment efficiency. The commonly used materials include gravel,

sand, activated charcoal, coconut coir, and brick bats.

Gravel and sand provide mechanical filtration by removing suspended particles. Activated charcoal helps in adsorption of organic compounds, color, and odor. Coconut coir and bio-media support microbial growth, enhancing biological degradation. The selection of media depends on availability, cost, and required treatment efficiency.

Design and Operating Parameters

1 **Hydraulic Retention Time (HRT)**

Hydraulic Retention Time determines the duration for which greywater remains in the system. Adequate HRT ensures effective removal of pollutants. Typically, higher retention time improves filtration and biological treatment efficiency.

2 **Organic Loading Rate (OLR)**

The organic loading rate represents the amount of organic matter entering the system. Proper control of OLR is essential to maintain microbial activity and prevent system overloading.

3 **pH and Temperature**

The efficiency of treatment depends on pH and temperature conditions. The optimal pH range is generally between 6.5 and 8.5. Temperature influences microbial activity, with moderate temperatures supporting better biological degradation.

Flow Mechanism and Aeration

Adequate mixing ensures uniform carrier distribution and prevents dead zones. Aeration serves a dual purpose by supplying oxygen and maintaining carrier movement. Poor hydrodynamics can result in biofilm detachment or uneven treatment performance.

In the vertical trickling system, greywater flows downward through filter layers under gravity. Aeration is provided either naturally or through mechanical means to supply oxygen for microbial activity. Proper aeration enhances the breakdown of organic pollutants and prevents foul odors.

4. RESULTS

The greywater treatment system showed effective improvement in water quality. pH was stabilized to near neutral range. Turbidity and TSS were significantly reduced due to multi-media filtration. Moderate reduction in TDS was observed. BOD and COD values decreased considerably due to biological aeration, indicating efficient removal of organic pollutants. Overall, the treated water was found suitable for non- potable uses such as gardening and flushing.

R NO	TEST PARAMETER	BASIN, HAND WASH,KITCHEN	BIS SPECIFICATION 10500: 2012(Edn.2.2) NORMAL VALUES	
			Desirable Limits	Permissible Limits
1	Physical Appearance	Turbid	--	--
2	Odour	Soapy	Unobjectionable	--
3	Turbidity(N.T.U)	6.21	1	5
4	PH Value	8.4	6.5 to 8.5	No Relaxation
5	Flouride(as F)	0.43	1	1.5
6	Nitrates (as NO3)	41	45	No Relaxation
7	Total Dissolved Solids	772	500	2000
8	Iron (as Fe)	0.61	1	No Relaxation
9	Chlorides (as Cl)	190	250	1000
10	Total Hardness (as CaCo3)	454	200	600
11	Alkalinity(as CaCo3)	280	200	600
12	Permanent Hardness (as CaCo3)	174	--	--

Table 1. Expected Result

5. CONCLUSIONS

The study demonstrates that the vertical trickling sump filter combined with multi-media filtration and biological aeration is an effective method for greywater treatment. The system significantly reduces turbidity, TSS, BOD, and COD, improving overall water quality. It is low-cost, easy to operate, and suitable for small- scale domestic use.

Thus, the treated greywater can be safely reused for non-potable purposes, contributing to water conservation and sustainable water management.

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