DOI: 10.36297/vw.jei.v4i1.709

VW Engineering International, Volume: 4, Issue: 1, 09-11

Development and Performance Evaluation of a Low-Cost Filtration System for Industrial Wastewater Treatment Using Natural Materials

Irfanul Hak[1*], Pooja Raina[2*], Jitesh Rao[3*]

[1]Department of Environmental Engineering, University of Kashmir, Srinagar, India
[2]Department of Civil Engineering, Maharaja Ranjit Singh Punjab Technical University, Bathinda, India
[3]Department of Mechanical Engineering, Madan Mohan Malviya University of Technology,Gorakhpur, India
[*]Email: irfanul@uok.ac.in, poojarani@ptu.ac.in, jitesh.r@mmmu.ac.in

Received: Apr 28, 2022
Accepted: Apr 29, 2022
Published online: Apr 30, 2022

Abstract: Industrial wastewater discharge poses a significant threat to surface and groundwater resources due to the presence of suspended solids, heavy metals, organic pollutants, and chemical residues. Conventional treatment technologies, while effective, are often capital-intensive and energy-demanding, making them inaccessible to small- and medium-scale industries, particularly in developing regions. This study presents the development, experimental evaluation, and performance analysis of a low-cost filtration system utilizing locally available natural materials for industrial wastewater treatment. The filtration unit was designed using layered configurations of sand, gravel, activated charcoal derived from agricultural waste, and natural fibrous media. Laboratory-scale experiments were conducted to assess the system's efficiency in removing turbidity, total dissolved solids (TDS), chemical oxygen demand (COD), and selected heavy metals under varying flow rates and influent concentrations. Results indicate substantial removal efficiencies, with turbidity and suspended solids reduction exceeding 85%, while COD and heavy metal removal ranged between 60% and 75%. The findings demonstrate that natural material-based filtration systems offer a technically viable, environmentally sustainable, and economically feasible alternative for preliminary and secondary treatment of industrial wastewater.

Keywords: Industrial Wastewater Treatment, Natural Filtration Media, Low-Cost Engineering, Water Quality Improvement, Sustainable Treatment Systems

1. Introduction

Rapid industrialization has led to a substantial increase in wastewater generation containing complex mixtures of organic and inorganic contaminants. Industries such as textiles, food processing, electroplating, and small-scale manufacturing discharge effluents that, if untreated, cause severe environmental degradation and public health risks [1]. Although advanced treatment technologies such as membrane filtration, ion exchange, and advanced oxidation processes offer high removal efficiencies, their implementation is constrained by high operational costs, energy consumption, and maintenance requirements. Low-cost wastewater treatment technologies based on natural materials have gained increasing attention as sustainable alternatives. These systems rely on physical filtration, adsorption, and biological interactions to remove contaminants, offering simplicity and affordability. The present study focuses on the engineering development and experimental evaluation of a filtration system employing natural materials that are inexpensive, locally available, and environmentally benign.

2. Selection of Natural Filtration Materials

Material selection is a critical aspect of filtration system design. In this study, sand and gravel were chosen as primary filtration layers due to their proven effectiveness in removing suspended solids and turbidity. Activated charcoal was produced from coconut shells using controlled thermal activation, providing a high surface area for adsorption of organic pollutants and dissolved contaminants [2]. Natural fibrous material derived from jute was

 DOI: 10.36297/vw.jei.v4i1.709

incorporated as an additional filtration medium to enhance particulate trapping and provide support for microbial growth. These materials were selected based on cost, availability, mechanical stability, and environmental compatibility.

3. Filtration System Design and Experimental Setup

The filtration unit was designed as a vertical column system fabricated from polyvinyl chloride (PVC) with an internal diameter of 150 mm and a total height of 1.2 m. The filter media were arranged in stratified layers, with gravel at the base for structural support, followed by sand, activated charcoal, and fibrous material at the top. Synthetic industrial wastewater was prepared to simulate effluents containing suspended solids, organic matter, and trace heavy metals such as lead and chromium. Experiments were conducted at different flow rates ranging from 0.5 to 2.0 L/min to evaluate hydraulic performance and treatment efficiency. Influent and effluent samples were analyzed following standard methods for water and wastewater examination [3].

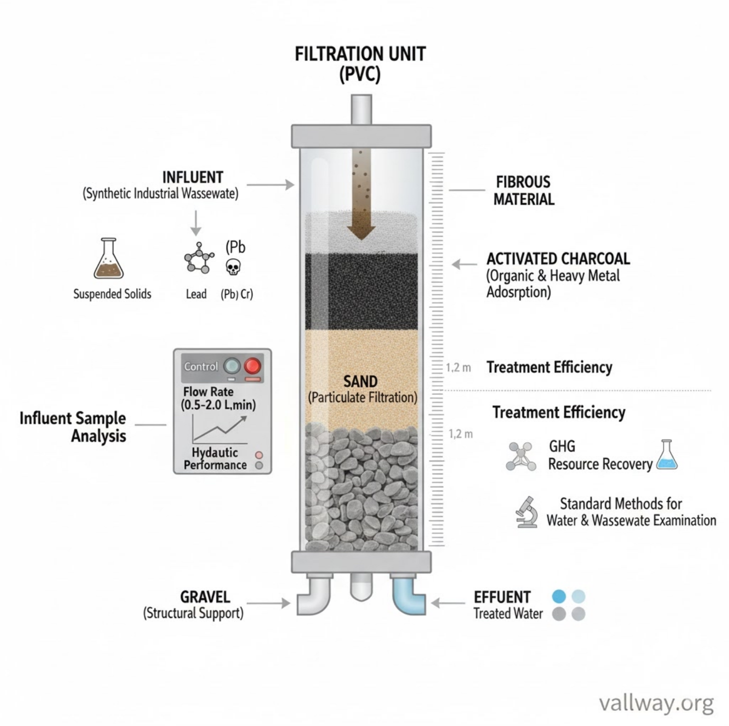

Fig. 1 Filtration

4. Performance Evaluation Parameters

The performance of the filtration system was evaluated using key water quality indicators, including turbidity, total dissolved solids, chemical oxygen demand, pH, and heavy metal concentration. Turbidity was measured using a nephelometric turbidity unit (NTU) meter, while COD was determined using the dichromate reflux method. Heavy metal concentrations were analyzed using atomic absorption spectroscopy. Removal efficiency was calculated based on influent and effluent concentration differences, and system stability was assessed over repeated operational cycles.

5. Results and Discussion

Experimental results demonstrate that the filtration system achieved significant improvement in wastewater quality. Turbidity removal exceeded 85% across all flow rates, indicating effective particulate filtration. COD reduction ranged between 62% and 71%, attributed primarily to adsorption by activated charcoal and biofilm formation on fibrous media [4]. Heavy metal removal efficiencies varied depending on influent concentration, with lead and chromium removal reaching up to 75% under optimal flow conditions. The system exhibited stable performance over multiple cycles with minimal clogging, highlighting its operational reliability. Compared to conventional treatment methods, the developed system offers moderate treatment efficiency at a fraction of the cost, making it suitable for decentralized and preliminary treatment applications.

6. Economic and Environmental Assessment

 DOI: 10.36297/vw.jei.v4i1.709

A preliminary cost analysis revealed that the capital cost of the filtration unit was significantly lower than that of conventional treatment systems. The use of agricultural waste-derived activated charcoal further reduced material expenses while promoting resource reuse. Environmentally, the system minimizes chemical usage and energy consumption, resulting in a low carbon footprint. Spent filtration media can be regenerated or safely disposed of with minimal environmental impact.

7. Limitations and Future Scope

While the system demonstrates promising performance, it is primarily suited for small-scale and decentralized applications. Long-term performance under continuous industrial operation and the regeneration efficiency of activated charcoal require further investigation. Future research should focus on hybridizing natural filtration systems with biological or electrochemical processes to enhance removal efficiency and broaden applicability.

8. Conclusion

This study successfully demonstrates the feasibility of a low-cost, natural material-based filtration system for industrial wastewater treatment. The experimental results confirm that significant contaminant removal can be achieved using simple engineering design and locally available materials. Such systems offer a sustainable solution for industries seeking affordable wastewater treatment options, particularly in resource-limited settings.

References

1. M. Metcalf and H. Eddy, Wastewater Engineering: Treatment and Resource Recovery, McGraw-Hill, 2014.
2. A. Bhatnagar and M. Sillanpää, “Utilization of agro-industrial wastes for water treatment,” Chemical Engineering Journal, vol. 157, no. 2, pp. 277–296, 2010.
3. APHA, Standard Methods for the Examination of Water and Wastewater, 22nd ed., Washington, DC, 2012.
4. Babel and T. A. Kurniawan, “Low-cost adsorbents for heavy metals uptake,” Journal of Hazardous Materials, vol. 97, no. 1–3, pp. 219–243, 2003.
5. R. Crini, “Non-conventional low-cost adsorbents for dye removal,” Bioresource Technology, vol. 97, no. 9, pp. 1061–1085, 2006.