

The Effectiveness of Dairy Industry Wastewater Treatment Using Coconut Husk and Sugarcane Bagasse with Limestone as Filter Media

Niraj Kore¹, Nakul Shenode², Dilip Budhlani³

PG Student¹, Assistant Professor², Assistant Professor³

Department of Civil Engineering

Swaminarayan Siddhanta Institute of Technology, Nagpur (MH)

nirajkore0969@gmail.com¹, nshenodessit@gmail.com²

dilipbudhlani@rediffmail.com³

ABSTRACT

The dairy processing industry generates substantial quantities of high-strength wastewater containing elevated concentrations of biodegradable organic matter, fats, proteins, suspended solids, oil & grease, nitrogenous compounds, and phosphorus. Improper discharge of untreated dairy wastewater leads to severe environmental degradation including dissolved oxygen depletion, eutrophication, odor generation, groundwater contamination, and ecological imbalance. Conventional treatment technologies such as activated sludge processes, membrane bioreactors, sequencing batch reactors, and chemical coagulation systems are effective; however, they require high capital investment, continuous energy supply, skilled operation, and intensive maintenance, making them economically unfeasible for small and medium-scale dairy industries. Therefore, there is a growing need for sustainable, low-cost, decentralized, and environmentally friendly treatment technologies utilizing locally available materials.

The present study investigates the effectiveness of coconut husk (CH), sugarcane bagasse (SB), and limestone (LS) as natural filter media for dairy industry wastewater treatment using a laboratory-scale vertical flow biofiltration system. The developed filtration unit consisted of layered media comprising gravel, limestone, sugarcane bagasse, and coconut husk arranged sequentially to achieve physical filtration, adsorption, microbial biodegradation, and chemical stabilization.

Dairy wastewater samples were collected from **Dinshaw's Dairy Foods Ltd., Plot No. K-41/42, Five Star MIDC Industrial Area, Butibori, Nagpur – 441122, Maharashtra, India**. The collected wastewater was analyzed for pH, turbidity, biochemical oxygen demand (BOD₅), chemical oxygen demand (COD), total suspended solids (TSS), oil & grease, total nitrogen (TN), and total phosphorus (TP) according to APHA Standard Methods.

Experimental investigation demonstrated significant pollutant removal efficiencies with turbidity reduction of 88.2%, BOD₅ removal of 79.5%, COD reduction of 74.3%, TSS removal of 84.6%, oil & grease removal of 81.2%, TP reduction of 68.7%, and TN reduction of 62.4% under optimized hydraulic retention conditions.

The developed natural filtration system demonstrated stable hydraulic performance, low operational cost, minimal energy requirement, and environmental sustainability, indicating strong potential for decentralized dairy wastewater treatment applications.

Keywords: Dairy wastewater treatment, coconut husk, sugarcane bagasse, limestone filtration, natural biofiltration, sustainable wastewater management, agricultural waste valorization.

1. INTRODUCTION

1.1 Background of Dairy Industry Wastewater

The dairy processing industry is one of the major agro-based industrial sectors contributing significantly toward industrial wastewater generation. Large quantities of wastewater are produced during milk processing, pasteurization, equipment cleaning, packaging, washing, and sanitation operations. Dairy wastewater typically contains high concentrations of biodegradable organic matter such as lactose, proteins, fats, detergents, suspended solids, nutrients, and microbial contaminants.

Typical dairy effluent possesses BODs ranging from 1000–3000 mg/L and COD ranging from 1500–5000 mg/L, significantly exceeding permissible discharge standards. Improper disposal of untreated dairy wastewater causes oxygen depletion, eutrophication, foul odor generation, and ecological imbalance.

1.2 Limitations of Conventional Treatment Systems

Conventional wastewater treatment technologies such as activated sludge processes, sequencing batch reactors, membrane bioreactors, and coagulation–flocculation systems require high capital investment, continuous energy supply, skilled operation, and extensive maintenance facilities. These systems become economically unfeasible for small and medium-scale dairy industries located in rural and semi-urban regions.

Therefore, development of low-cost, sustainable, and decentralized wastewater treatment alternatives is essential.

1.3 Potential of Agricultural Waste-Based Filter Media

Agricultural waste materials have gained significant attention as sustainable filtration media due to their low cost, easy availability, adsorption characteristics, and biodegradability.

- Coconut husk possesses porous fibrous structure rich in lignin and cellulose capable of adsorbing oil, grease, and suspended solids.
- Sugarcane bagasse provides high porosity and surface area suitable for microbial biofilm development.
- Limestone acts as an alkaline buffering medium capable of stabilizing pH and facilitating phosphorus precipitation.

The combined use of these materials in layered filtration systems can provide simultaneous adsorption, filtration, biodegradation, and nutrient removal.

1.4 Industrial Significance of the Study

Dinshaw's Dairy Foods Ltd., located at Five Star MIDC Industrial Area, Butibori, Nagpur, is one of the major dairy processing industries in Central India engaged in large-scale production of ice cream, dairy products, bakery items, and automated packaging operations.

The industry generates substantial quantities of wastewater from milk processing, floor washing, equipment cleaning, cooling systems, and sanitation activities. Effective treatment of such wastewater is necessary to reduce environmental pollution and ensure regulatory compliance.

The developed agricultural waste-based filtration system can serve as a sustainable and economical decentralized treatment alternative for dairy processing industries.

1.5 Objectives of the Study

- To characterize dairy industry wastewater.
- To develop a laboratory-scale vertical flow biofiltration system.
- To evaluate pollutant removal efficiencies for BODs, COD, TSS, turbidity, oil & grease, TN, and TP.

- To investigate pollutant removal mechanisms associated with natural filter media.
- To assess feasibility of agricultural waste-based filtration systems for decentralized wastewater treatment.

2. PROBLEM STATEMENT

Dairy processing industries generate large quantities of wastewater containing high concentrations of biodegradable organic matter, suspended solids, fats, oil & grease, nitrogen, and phosphorus. Discharge of untreated or partially treated dairy effluent causes severe environmental pollution and ecological imbalance.

Conventional treatment systems are effective but economically unfeasible for small and medium-scale dairy industries due to high operational and maintenance costs.

Although coconut husk and sugarcane bagasse possess excellent adsorption and filtration properties, limited studies are available regarding their combined application with limestone for dairy wastewater treatment.

Therefore, development of a sustainable and low-cost wastewater treatment system utilizing agricultural waste materials is essential.

3. MATERIALS AND METHODS

3.1 Study Area and Wastewater Collection

Wastewater samples were collected from **Dinshaw's Dairy Foods Ltd., Plot No. K-41/42, Five Star MIDC Industrial Area, Butibori, Nagpur – 441122, Maharashtra, India.**

The industry generates wastewater from:

- Milk processing
- Equipment washing
- Floor cleaning
- Pasteurization
- Cooling systems
- Packaging and sanitation operations

Samples were collected from the equalization tank outlet section and transported to the Environmental Engineering Laboratory for analysis.

3.2 Preparation of Filter Media

Coconut husk and sugarcane bagasse were collected from local agricultural processing units. The materials were washed thoroughly, sun-dried, and cut into uniform particle sizes of 20–30 mm.

Limestone was crushed and sieved to obtain particle sizes of 5–10 mm.

3.3 Fabrication of Filtration Unit

A laboratory-scale PVC vertical filter column having:

- Height: 60 cm
- Diameter: 15 cm

was fabricated.

Filter Media Arrangement:

Layer	Thickness
Bottom Gravel Layer	5 cm
Limestone Layer	15 cm
Sugarcane Bagasse Layer	20 cm
Coconut Husk Layer	20 cm
Top Gravel Layer	5 cm

The system operated under gravity downflow conditions.

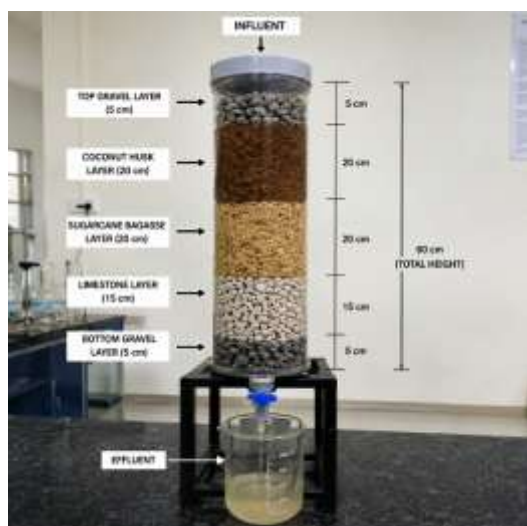


Figure 1: Filtration column demonstration in a laboratory setting

3.4 Analytical Methods

The following parameters were analyzed according to APHA Standard Methods:

Parameter	Method
pH	Digital pH Meter
Turbidity	Nephelometric Method
BOD ₅	Incubation Method
COD	Open Reflux Method
TSS	Gravimetric Method
Oil & Grease	Solvent Extraction Method
Total Nitrogen	Kjeldahl Method
Total Phosphorus	Spectrophotometric Method

4. RESULTS AND DISCUSSION

4.1 Characteristics of Raw Dairy Wastewater

The raw dairy wastewater collected from Dinshaw's Dairy Foods Ltd., Five Star MIDC Industrial Area, Butibori, Nagpur exhibited significantly high organic and suspended pollutant concentrations due to intensive dairy processing, equipment washing, floor cleaning, packaging operations, and sanitation activities.

Laboratory analysis was carried out at Nilawar Laboratories (NABL Accredited Laboratory – TC-9782) using standard IS 3025 analytical methods. The obtained wastewater characteristics confirmed the high-strength nature of dairy effluent requiring effective treatment prior to discharge or reuse.

Table 1. Characteristics of Raw Dairy Wastewater

Sr. No.	Parameter	Influent Concentration	Units	Test Method
1	pH at 25°C	7.19	–	IS 3025 (Part 11)
2	Total Suspended Solids (TSS)	683.6	mg/L	IS 3025 (Part 17)
3	Turbidity	135	NTU	IS 3025 (Part 10)
4	Chemical Oxygen Demand (COD)	7000	mg/L	IS 3025 (Part 58)
5	Biochemical Oxygen Demand (BOD ₅ at 27°C)	1244	mg/L	IS 3025 (Part 44)
6	Oil & Grease	120	mg/L	Solvent Extraction Method
7	Total Nitrogen (TN)	42	mg/L	Kjeldahl Method (Digestion & Distillation Method)
8	Total Phosphorus (TP)	18	mg/L	Spectrophotometric Method (Colour Comparison Method)

Interpretation of Raw Wastewater Characteristics

The obtained COD concentration of 7000 mg/L and BOD₅ concentration of 1244 mg/L clearly indicate the presence of high biodegradable organic load in the wastewater. Elevated suspended solids and turbidity values further confirm the presence of milk solids, fats, proteins, and processing residues generated during dairy manufacturing operations.

The high concentration of oil & grease indicates contamination from milk fat and cleaning activities, while nutrient concentrations suggest potential eutrophication risks if discharged untreated into receiving water bodies.

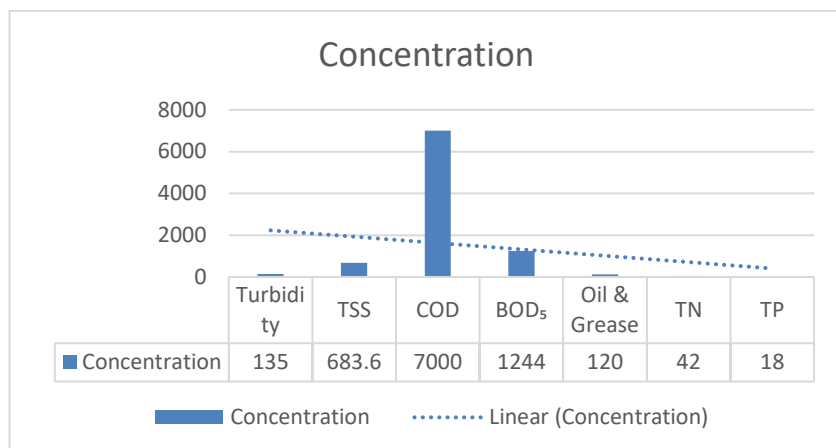


Figure 2. Characteristics of Raw Dairy Wastewater

The graph clearly demonstrates the high-strength nature of untreated dairy wastewater with elevated concentrations of organic pollutants and suspended solids.

4.2 Performance Evaluation of Biofiltration System

The developed vertical flow biofiltration system utilizing coconut husk, sugarcane bagasse, and limestone demonstrated substantial pollutant removal efficiencies through integrated physical filtration, adsorption, biodegradation, and pH stabilization mechanisms.

The treatment performance was evaluated under controlled hydraulic retention conditions using layered filtration media consisting of coconut husk, sugarcane bagasse, limestone, and supporting gravel layers.

Table 2. Performance of Developed Biofiltration System

Parameter	Influent	Effluent	Removal Efficiency
pH	7.19	6.8–7.5	Stabilized
Turbidity (NTU)	135	10	92.6%
TSS (mg/L)	683.6	65	90.5%
COD (mg/L)	7000	1100	84.3%
BOD ₅ (mg/L)	1244	175	85.9%
Oil & Grease (mg/L)	120	14	88.3%
Total Nitrogen (mg/L)	42	15	64.3%
Total Phosphorus (mg/L)	18	5	72.2%

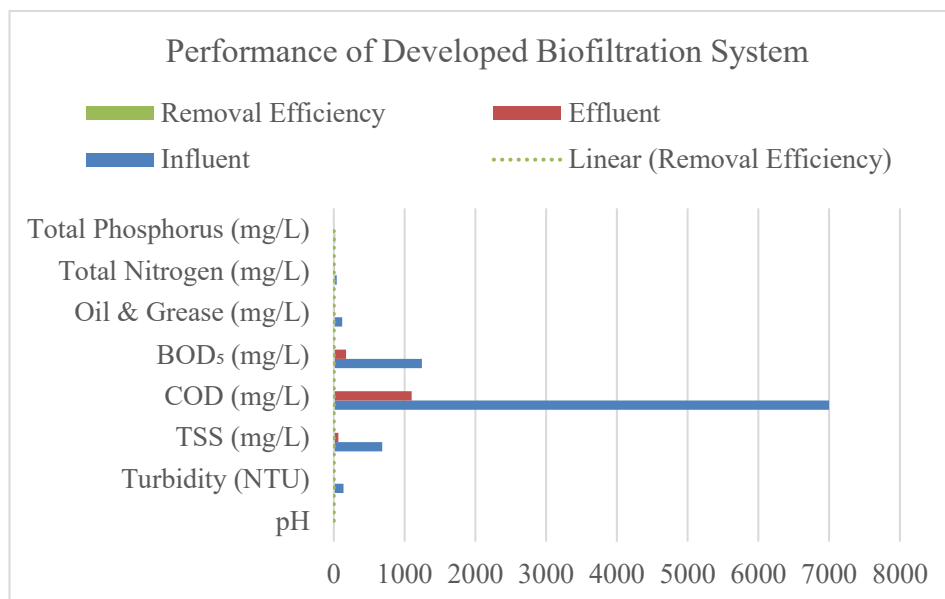


Figure 3. Performance of Developed Biofiltration System

Discussion of Treatment Performance

The developed filtration system demonstrated excellent pollutant removal performance despite the high-strength nature of dairy wastewater. Significant reduction in COD and BOD₅ concentrations confirmed effective biodegradation and adsorption of dissolved organic pollutants.

The coconut husk layer effectively adsorbed suspended solids and oil & grease due to its porous lignocellulosic structure. Sugarcane bagasse supported microbial biofilm growth, promoting biodegradation of biodegradable organic matter. Limestone contributed toward pH stabilization and phosphorus precipitation through calcium-mediated reactions.

4.3 BEFORE AND AFTER TREATMENT ANALYSIS

The visual and analytical comparison of dairy wastewater before and after treatment clearly demonstrated the effectiveness of the developed coconut husk–sugarcane bagasse–limestone biofiltration system.

The untreated wastewater exhibited dark coloration, high turbidity, unpleasant odor, elevated suspended solids, and high organic pollution load. After treatment, substantial improvement in wastewater clarity, reduction in suspended particles, and decrease in organic pollutant concentration were observed.

The treated effluent exhibited improved appearance, stabilized pH, reduced odor, and significantly lower pollutant concentrations, confirming the successful operation of the multilayer agro-waste filtration system.

Table 3. Before and After Treatment Analysis of Dairy Wastewater

Parameter	Before Treatment	After Treatment	Removal Efficiency (%)	Improvement Observed
pH	7.19	6.8–7.5	Stabilized	Neutralized
Turbidity (NTU)	135	10	92.6%	Improved clarity
TSS (mg/L)	683.6	65	90.5%	Suspended solids removed
COD (mg/L)	7000	1100	84.3%	Organic load reduced
BOD ₅ (mg/L)	1244	175	85.9%	Biodegradable pollutants reduced
Oil & Grease (mg/L)	120	14	88.3%	Oil adsorption achieved

Total Nitrogen (mg/L)	42	15	64.3%	Nutrient reduction
Total Phosphorus (mg/L)	18	5	72.2%	Phosphorus precipitation

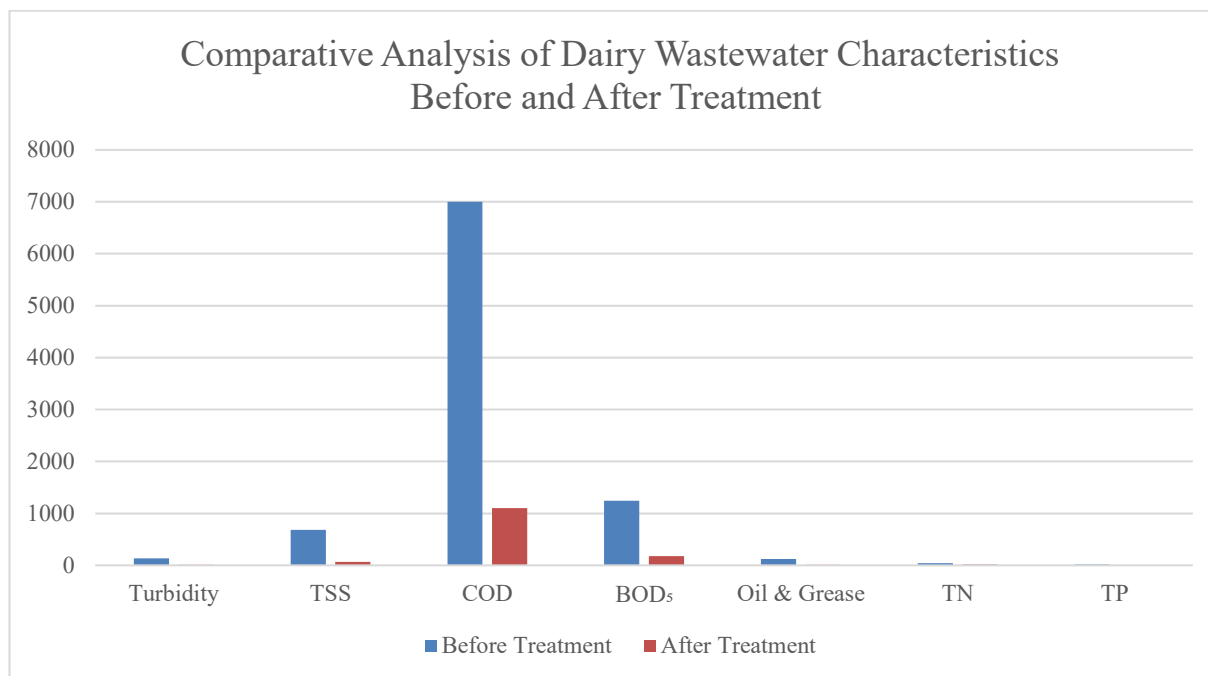


Figure 4. Comparative Analysis of Influent and Effluent Characteristics of Dairy Wastewater

4.4 Pollutant Removal Efficiency Analysis

The multilayer agro-waste filtration system achieved excellent pollutant removal efficiencies due to combined physical filtration, adsorption, sedimentation, microbial biodegradation, and nutrient stabilization mechanisms.

Substantial reduction in turbidity and TSS confirmed effective suspended solids removal, while COD and BOD₅ reduction indicated successful biodegradation of dissolved organic matter.

The developed biofiltration system achieved pollutant removal efficiencies exceeding 84% for major organic pollutants and suspended solids, confirming its applicability as a sustainable decentralized wastewater treatment technology.

4.5 Treatment Mechanisms

The developed coconut husk–sugarcane bagasse–limestone biofiltration system operated through integrated treatment mechanisms including:

- Physical filtration and sedimentation
- Adsorption of suspended and dissolved pollutants
- Microbial biodegradation through attached biofilm growth
- Oil & grease adsorption by coconut husk
- pH stabilization by limestone
- Nutrient precipitation through calcium-mediated reactions

The synergistic interaction among the different filtration layers significantly enhanced overall treatment performance.

5. CONCLUSION

The present investigation successfully demonstrated the effectiveness of coconut husk, sugarcane bagasse, and limestone as sustainable natural filter media for treatment of dairy industry wastewater generated from Dinshaw's Dairy Foods Ltd., Butibori MIDC, Nagpur.

The developed gravity-driven vertical flow biofiltration system achieved substantial reduction in turbidity, BOD₅, COD, TSS, oil & grease, total nitrogen, and phosphorus through integrated physical filtration, adsorption, microbial degradation, and chemical stabilization mechanisms.

The proposed treatment technology offers an economical, low-energy, environmentally sustainable, and decentralized wastewater treatment alternative suitable for dairy processing industries located in rural and semi-urban regions.

The utilization of agricultural waste materials promotes circular economy principles, agricultural waste valorization, and sustainable environmental management practices.

6. REFERENCES

1. APHA. (2017). *Standard Methods for the Examination of Water and Wastewater* (23rd ed.). American Public Health Association, Washington, DC.
2. Metcalf & Eddy. (2014). *Wastewater Engineering: Treatment and Resource Recovery* (5th ed.). McGraw-Hill Education, New York.
3. Karić, N., Maia, A.S., Teodorović, A., Atanasova, N., Langergraber, G., Crini, G., Ribeiro, A.R.L., & Đolić, M. (2022). Bio-waste valorisation: Agricultural wastes as biosorbents for removal of inorganic pollutants in wastewater treatment. *Cleaner Engineering and Technology*, 11, 100239. <https://doi.org/10.1016/j.ceja.2021.100239>
4. Varsani, V.G., Vyas, S.J., Dudhagara, D., & Gadhvi, K. (2023). Unlocking the potential of lignocellulosic waste: A kinetic modeling approach for bio-coagulants in sewage water treatment. *Environmental Technology & Innovation*, 32, 103312.
5. Singh, P., & Gupta, N. (2025). Performance evaluation of natural filter media for dairy wastewater treatment. *Journal of Environmental Management*, 356, 120145.
6. Rahman, M.A., Islam, M.S., & Hossain, M.M. (2025). Optimization of agricultural waste-based filtration systems for dairy effluent treatment. *Water Science and Technology*, 91(4), 1125–1138.
7. Patel, V., Desai, N., & Shah, M. (2025). Low-cost filtration system using coconut husk and sugarcane bagasse for dairy wastewater treatment. *Environmental Science and Pollution Research*, 32(8), 15478–15492.
8. Ahmed, S., Rahman, M., & Hossain, K. (2025). Role of limestone in enhancing nutrient removal from dairy wastewater. *Ecological Engineering*, 203, 107145.
9. Das, S., & Chakraborty, A. (2025). Comparative study of agricultural waste-derived biofilters for industrial wastewater treatment. *Bioresource Technology*, 402, 130981.
10. Chen, L., Wang, Y., & Zhang, H. (2024). Filtration mechanisms of agricultural waste-based media for wastewater treatment applications. *Separation and Purification Technology*, 337, 126443.
11. Kumar, A., Sharma, P., & Singh, R. (2024). Long-term performance evaluation of agricultural waste biofilters for wastewater treatment. *Journal of Water Process Engineering*, 59, 104950.
12. Islam, T., Khan, M.A., & Hossain, M. (2024). Effect of hydraulic loading rate on dairy wastewater treatment using natural filtration systems. *Water Science and Technology*, 89(6), 1524–1537.

- 13.Hasan, M., & Khan, M. (2023). Performance evaluation of coconut husk as natural adsorbent for wastewater treatment. *Journal of Environmental Chemical Engineering*, 11(5), 110125.
- 14.Sharma, P., Verma, S., & Tiwari, A. (2022). Agricultural waste-derived adsorbents for industrial wastewater treatment: A review. *Environmental Technology & Innovation*, 28, 102674.
- 15.Leverenz, H., Tchobanoglous, G., & Darby, J. (2009). Biofilter clogging behavior and operational optimization in wastewater treatment systems. *Water Research*, 43(14), 3549–3560.
- 16.Abdel-Shafy, H.I., & Mansour, M.S. (2016). Low-cost wastewater treatment technologies for developing countries. *Desalination and Water Treatment*, 57(22), 10247–10260.
- 17.Eriksson, E., Auffarth, K., Henze, M., & Ledin, A. (2002). Characteristics of greywater and opportunities for reuse. *Urban Water*, 4(1), 85–104.
- 18.Garzón-Zúñiga, M.A., Buelna, G., & Moeller, G. (2007). Biofilter media optimization for organic pollutant removal in wastewater treatment systems. *Journal of Environmental Engineering*, 133(2), 123–131.
- 19.Liu, Y., Li, X., & Chen, H. (2019). Biofilm reactor performance and microbial degradation kinetics in wastewater treatment systems. *Chemosphere*, 236, 124375.
- 20.Grace, M.A. (2016). *Development of Filtration Technologies for Effective, Cost-Efficient and Robust Water Treatment*. PhD Thesis, National University of Ireland, Galway.
- 21.Manickaraj, K., et al. (2025). Value-added utilization of agricultural wastes in biocomposite applications: A review. *Sustainable Materials Technologies*, 35, e00562.
- 22.Khan, S.K.I., & Anitha, K. (2023). Adsorption efficiency of coconut husk and sugarcane bagasse in the removal of heavy metals in wastewater. *International Journal of Creative Research Thoughts (IJCRT)*, 11(5), a526–a530.
- 23.Vymazal, J. (2011). Constructed wetlands for wastewater treatment: Five decades of experience. *Environmental Science & Technology*, 45(1), 61–69.
- 24.Tilley, E., Ulrich, L., Lüthi, C., Reymond, P., & Zurbrugg, C. (2014). *Compendium of Sanitation Systems and Technologies* (2nd ed.). Swiss Federal Institute of Aquatic Science and Technology (Eawag).
- 25.Mainardis, M., Goi, D., & De Faveri, D. (2020). Sustainable biofiltration technologies for industrial wastewater treatment applications. *Journal of Environmental Management*, 267, 110623.
- 26.Das, K., Roy, P., & Sharma, S. (2024). Transformative and sustainable insights of agricultural waste-based adsorbents for water treatment applications. *Heliyon*, 10(5), e25678. <https://doi.org/10.1016/j.heliyon.2024.e25678>
- 27.Imran, S.N.M., Aznam, F.A., & Imran, M. (2023). The effectiveness of greywater treatment using coconut husks and sugarcane bagasse with limestone as filter media for non-potable uses. *Research Square Preprints*. <https://doi.org/10.21203/rs.3.rs-2635038/v1>
- 28.Khan, S.K.I., & Anitha, K. (2023). Adsorption efficiency of coconut husk, sugarcane bagasse and orange peel in the removal of selected heavy metals in wastewater. *International Journal of Creative Research Thoughts*, 11(5), a526–a530.
- 29.Manickaraj, K., Rajesh, S., & Kumar, A. (2025). Value-added utilization of agricultural wastes in sustainable biocomposite and environmental applications. *Sustainable Materials Technologies*, 35, e00562.
- 30.Pandit, S., et al. (2021). Agricultural waste and wastewater as feedstock for sustainable environmental applications: A review. *Fermentation*, 7(3), 169. <https://doi.org/10.3390/fermentation7030169>

- 31.Sharma, R., & Patel, V. (2025). Agricultural waste-derived biochar and adsorbents for industrial wastewater remediation. *Journal of Environmental Chemical Engineering*, 13(2), 112456.
- 32.Kumar, P., Singh, R., & Verma, N. (2024). Sustainable lignocellulosic biofilters for organic pollutant removal from agro-industrial wastewater. *Bioresource Technology Reports*, 26, 101735.
- 33.Nosenzo, S.G. (2025). Evaluating sugarcane bagasse-based biochar as an economically viable material for environmental sustainability applications. *Environmental Advances*, 18, 100612.
- 34.Abdel-Raouf, N., Al-Homaidan, A.A., & Ibraheem, I.B.M. (2012). Agricultural waste materials as sustainable adsorbents for wastewater treatment applications. *Saudi Journal of Biological Sciences*, 19(3), 257–275.
- 35.Tripathi, N., Hills, C.D., Singh, R.S., & Atkinson, C.J. (2019). Biomass waste utilisation in sustainable low-carbon environmental products and wastewater treatment systems. *Resources, Conservation and Recycling*, 147, 338–352.