

Evaluation of Dairy Industry Wastewater Treatment Efficiency Using Coconut Husk, Sugarcane Bagasse, and Limestone as Filter Media

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ABSTRACT

The dairy industry generates large volumes of wastewater rich in biodegradable organic matter, fats, proteins, suspended solids, oil and grease, nitrogen, and phosphorus. Untreated discharge can cause environmental problems such as oxygen depletion, eutrophication, groundwater contamination, odor issues, and ecosystem degradation. Although conventional treatment methods are effective, their high cost, energy requirements, and maintenance need often limit their application in small and medium-scale dairies. This study evaluates the effectiveness of coconut husk, sugarcane bagasse, and limestone as low-cost, eco-friendly filter media in a laboratory-scale vertical flow biofiltration system. The filtration unit employed layered gravel, limestone, sugarcane bagasse, and coconut husk to facilitate physical filtration, adsorption, microbial degradation, and chemical stabilization of dairy wastewater.

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 a major source of industrial wastewater generated from milk processing, pasteurization, equipment cleaning, packaging, and sanitation activities. Dairy effluent contains high levels of biodegradable organic matter, including lactose, proteins, fats, suspended solids, nutrients, detergents, and microorganisms. Typical wastewater exhibits BOD₅ concentrations of 1000–3000 mg/L and COD concentrations of 1500–5000 mg/L, often exceeding discharge standards. Untreated disposal can lead to oxygen depletion, eutrophication, foul odors, and ecological damage.

1.2 Limitations of Conventional Treatment Systems

Conventional treatment methods such as activated sludge processes, sequencing batch reactors, membrane bioreactors, and coagulation–flocculation systems are effective but require substantial capital investment, continuous energy input, skilled operation, and regular maintenance. These requirements make them less suitable for small and medium-scale dairy industries, particularly in rural and semi-urban areas. Therefore, affordable, sustainable, and decentralized treatment alternatives are needed.

1.3 Potential of Agricultural Waste-Based Filter Media

Agricultural waste materials offer a low-cost and environmentally friendly option for wastewater treatment due to their availability, adsorption capacity, and biodegradability. Coconut husk can effectively adsorb oil, grease, and suspended solids because of its porous fibrous structure. Sugarcane bagasse provides a large surface area that supports microbial biofilm growth and biodegradation. Limestone helps maintain pH balance and promotes phosphorus removal through precipitation. Together, these materials can enhance filtration, adsorption, biodegradation, and nutrient removal in a layered treatment system.

1.4 Industrial Significance of the Study

This study is relevant to dairy industries such as Dinshaw's Dairy Foods Ltd., located in the Five Star MIDC Industrial Area, Butibori, Nagpur, which generates considerable wastewater from milk processing, equipment cleaning, floor washing, cooling operations, and sanitation activities. Effective treatment is essential to minimize environmental impacts and meet regulatory standards. The proposed filtration system using agricultural waste materials provides a sustainable, economical, and decentralized wastewater treatment

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 BOD₅, 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.

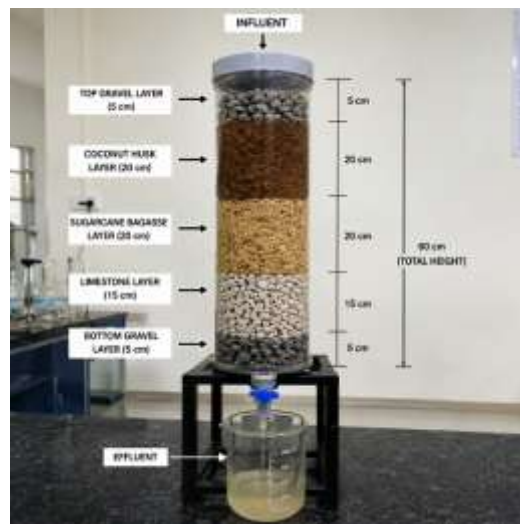


Figure 1: Filtration column demonstration in a laboratory setting

3.4 Analytical Methods

The following parameters were analysed 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.

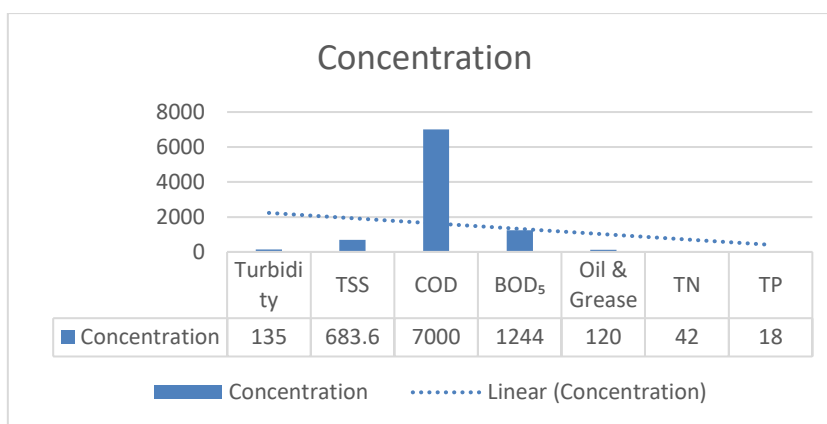


Figure 2. Characteristics of Raw Dairy Wastewater

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

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.

4.2 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.

4.3 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.

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