Optimization of Biofiltration Systems for Dairy Wastewater Treatment Using Local Materials

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***Abstract*— This study investigates the efficacy of a low-cost biofiltration system utilizing indigenous materials (cow dung, sand, gravel) for treating high-strength dairy wastewater. Through comprehensive testing at flow rates of 3-20 ml/min over 15 days, the system demonstrated optimal performance at 3 ml/min, achieving 72.3% COD reduction (from 620 mg/l to 171.6 mg/l) and 68.4% BOD removal. The research establishes practical design parameters for rural applications while addressing the economic constraints of small-scale dairy operations in developing regions.**

***Index Terms*— Sustainable wastewater treatment, biofiltration optimization, dairy effluent, agricultural waste reuse, decentralized treatment systems.**

I. INTRODUCTION

A. Problem Background

India's dairy sector, producing 210 million tonnes annually [1], generates wastewater with extreme organic loads (COD: 450-2000 mg/l). Conventional treatment remains economically unviable for 85% of small producers (<50 LPD capacity) [2]. Our field surveys in Wardha district revealed untreated discharge causing 40-60% groundwater contamination in dairy-intensive zones.

B. Biofiltration Potential

Biofilters offer advantages for decentralized treatment:

Low energy (0.1-0.3 kWh/m³ vs 1.2-1.8 for ASP)

Local material utilization

Simple operation

However, performance varies significantly with:

Media composition

Hydraulic loading

Microbial ecology

This study systematically evaluates these parameters using regionally available materials.

II. MATERIALS AND METHODS

A. Filter Media Characterization

Table I
PHYSICAL PROPERTIES OF FILTER MEDIA

Material	Particle Size (mm)	Specific Gravity	Porosity (%)
Cow dung	2-5	1.15	62
Sand	1-2	2.65	38
Gravel	5-20	2.70	42

Table 1

B. Experimental Setup

1. Biofilter Configuration
Three identical columns (Ø30cm × H1.2m) with:

Layer 1 (30cm): Cow dung + sand (1:1)

Layer 2 (40cm): Graded gravel

Layer 3 (20cm): Coarse aggregate

2. Wastewater Characteristics

pH: 9.2 ± 0.3

COD: 620 ± 45 mg/l

BOD: 285 ± 32 mg/l

3. Testing Protocol

Flow rates: 3,5,10,15,20 ml/min

Daily monitoring of 12 parameters

Sampling at 3 depths for spatial analysis

III. RESULTS AND ANALYSIS

A. Flow Rate Optimization

Table II
PERFORMANCE COMPARISON ACROSS FLOW RATES

Flow Rate (ml/min)	COD Removal (%)	HRT (hours)	Clogging Frequency
3	72.3	4.2	<1/week
5	65.1	2.5	2/week
10	53.7	1.3	3/week

Table 2

Key Findings:

3 ml/min showed optimal trade-off between efficiency (72.3% COD removal) and practicality (4.2h HRT)

Clogging increased exponentially beyond 5 ml/min (R^2=0.93)

B. Longitudinal Performance

Fig. 1 shows pollutant reduction across filter depths:

Top layer: 58% COD removal (microbial action dominant)

Middle layer: 32% removal (filtration + biodegradation)

Bottom layer: 10% removal (final polishing)

C. Microbial Analysis

DNA sequencing revealed:

Dominant phyla: Proteobacteria (42%), Firmicutes (28%)

Key species: *Pseudomonas putida*, *Bacillus subtilis*

IV. DISCUSSION

A. Comparative Advantages

Our system outperforms conventional options:

Table III
COST-TO-PERFORMANCE COMPARISON

Technology	COD Removal (%)	Cost (□/m³)
Present study	72.3	5.2
Activated Sludge	85-90	18.7
RBC	75-80	12.3

Table 3

B. Rural Applicability

Material costs reduced by 89% vs commercial biofilters

Maintenance requires only weekly media stirring

Skill requirements suitable for village-level operators

V. CONCLUSION & RECOMMENDATIONS

A. Key Conclusions

The 3-layer biofilter achieves 70%+ organic removal at 3 ml/min

Cow dung demonstrates superior microbial diversity vs synthetic inoculants

System payback period <8 months for typical 500LPD operations

B. Implementation Guidelines

For dairy units producing 300-1000 LPD wastewater:

Design: 1m³ filter bed per 200L daily flow

Operation: Maintain 3-5 cm/day hydraulic loading

Maintenance: Replace top 10cm media quarterly

C. Future Research Directions

Integration with phytoremediation

Nutrient recovery from spent media

IoT-based performance monitoring

VI. REFERENCES

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