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PERFORMANCE EVALUATION OF IMPROVED ANAEROBIC BAFFLE FILTER REACTOR IN TREATING DOMESTIC WASTEWATER

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ABSTRACT

An interest in better and sustainable wastewater systems has resulted in new, improved ABFRs. This research considers two upgraded ABFR and compares their abilities to treat domestic wastewater by measuring COD, BOD, TSS removal and efficiency of nutrient removal. The researchers used different HRT and OLR values to discover how the reactor would operate under various conditions. The ABFR system succeeded in taking out 85% of COD, 80% of BOD and eliminating much of TSS, all while being tested at the plant. The method explains that the reactor conserves energy, avoids producing too much sludge and is fitted for simple treatment plants.

Keywords: Anaerobic Baffle Filter Reactor (ABFR) Domestic wastewater treatment

1. INTRODUCTION

1.1 Background

The quick expansion of cities and the increase in some populations is making it difficult to monitor wastewater systems. Traditional, central water treatment is generally not practical in rural and peri-urban places because building and running these systems is costly and operators must be very knowledgeable (Massoud et al., 2009). Consequently, wastewater treatment technologies should be flexible, cost-friendly, tough and low maintenance.

Due to their energy efficiency, small waste and biogas benefits, anaerobic treatment systems are now widespread (Lettinga, 1995). It also seems that the ABFR might be suitable for operation at smaller treatment plants. Treating water with anaerobic digestion and filtration, ANFR gives better results in removing sewage than regular septic tanks and upflow anaerobic sludge blanket (UASB) reactors (Foxon et al., 2004). However, some standard biological filters can become blocked, provide inconsistent amounts of nutrients and leave some wastes behind which means they have to be improved.

1.2 Anaerobic Baffle Filter Reactor (ABFR) Technology

The ABFR is an adapted anaerobic system that uses baffles and filter material to promote exposure of wastewater to anaerobic microbes. Inclined or vertical baffles inside the reactor divide it into many sections, helping achieve flow plugging and minimizing short-circuiting (Barber & Stuckey, 1999).

2. MATERIALS AND METHODS

2.1 Reactor Design and Modifications

2.1.1 Reactor Configuration

A 50 L ABFR (measuring 0.25 m by 0.2 m by 1.2 m) using polypropylene and with all the holes in the shape of a square array was constructed. Both types of material were much simpler to handle and support within the reactor shell, thanks to the incline plates at 45° (see Figure 1). All compartments were created using their own special filter materials.

For the lower chamber, 25 mm polyethylene biofilm carriers are used to cultivate microbes over a wide area (350 m^2/m^3).

Four to six micrometer carbon beads are placed with the microorganisms in the top section so they can catch and store any extra organic substance.

Wastewater Characteristics

Wastewater is the result of

The details of the materials and anions used to make synthetic wastewater are given in Table 1 (Table 9).

Food waste has glucose, peptone and starch and its COD typically ranges from 300 to 600 mg/L.

Nutrients in water ought to be between 25 and 50 mg NH_4Cl per liter for nitrogen and 5 and 15 mg KH_2PO_4 per liter for phosphorus.

Add 100 to 200 milligrams of cellulose powder to about 40 to 60 ounces (a liter or more) of water.

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Table 1: Composition of synthetic domestic wastewater

Parameter	Concentration Range
COD	300–600 mg/L
BOD_5	150–350 mg/L
TSS	100–200 mg/L
NH_3-N	25–50 mg/L
PO_4^{3-}-P	5–15 mg/L
pH	6.5–7.5

3. RESULTS AND DISCUSSION

Table 2: Organic removal at different HRTs (OLR=1.5 kg COD/m^3/day)*

HRT (h)	COD Removal (%)	BOD_5 Removal (%)
6	72 ± 5	68 ± 6
12	82 ± 4	79 ± 5
24	89 ± 3	85 ± 4
48	92 ± 2	88 ± 3

The **hybrid media system** (bio-carriers + activated carbon) contributed to:

- 15% higher COD removal vs. conventional ABFR (no media)
- Improved biomass retention (VSS increased from 2.1 to 4.8 g/L after 60 days)

3.1.2 Impact of Organic Loading Rate

- **Low OLR (0.5 kg COD/m^3/day):** Stable but suboptimal removal (81±3% COD)
- **High OLR (3.0 kg COD/m^3/day):** Efficiency dropped to **65±7% COD removal**, with VFA accumulation (>200 mg/L as acetate)
- **Optimal range:** 1.0–2.0 kg COD/m^3/day (85–89% removal)

3.2 Solids and Nutrient Removal

3.2.1 TSS Reduction

- **Consistent TSS removal (78–85%)** across all HRTs
- **Baffle design** effectively trapped solids in first two compartments
- **Media section** captured finer particles (20–50 µm)

3.2.2 Nitrogen and Phosphorus Behavior

- **NH_3-N removal limited (15–25%)** due to anaerobic conditions
- **PO_4^{3-}-P reduction (30–40%)** attributed to:
- Microbial uptake
- Precipitation with Ca^{2+}/Mg^{2+} in wastewater

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- **Post-treatment recommendation:** Aerobic polishing needed for complete nutrient removal

3.3 Biogas Production and Energy Potential

- **Methane content:** 65–72% (typical for domestic sewage)
- **Yield:** 0.28±0.05 L CH_4/g CODremoved
- **Energy potential:** 1.1 kWh/m³ wastewater at 24h HRT

3.4 Comparative Performance Analysis

Table 3: ABFR vs. other anaerobic systems

System	COD Removal (%)	HRT (h)	OLR (kg COD/m³/day)
Improved ABFR	89	24	1.5
Conventional ABFR	74	24	1.5
UASB	85	8	3.0
Septic Tank	50–60	48–72	0.3–0.5

4. COMPARATIVE ANALYSIS WITH OTHER SYSTEMS

4.1 Performance Comparison

4.1.1 Treatment Efficiency

The improved ABFR demonstrated superior performance compared to conventional anaerobic systems (Table 4):

Table 4: Treatment efficiency comparison

System	COD Removal (%)	TSS Removal (%)	HRT (h)	Reference
Improved ABFR	85-89	78-85	24	This study
Conventional ABFR	70-75	65-70	24	Foxon et al. (2004)
UASB Reactor	80-85	70-75	6-8	Lettinga (1995)
Anaerobic Filter	75-80	60-65	12-18	Rajesh Banu et al. (2020)
Septic Tank	50-60	40-50	48-72	Massoud et al. (2009)

Key observations:

- **15-20% higher COD removal** than conventional ABFR
- **Comparable to UASB** but with longer HRT
- **Twice as effective** as septic tanks

4.1.2 Nutrient Removal

While all anaerobic systems showed limited nutrient removal, the improved ABFR exhibited marginally better performance:

- **NH_3-N removal:** 15-25% (vs. 10-20% in UASB)
- **PO_4^{3-}-P removal:** 30-40% (vs. 20-30% in anaerobic filters)

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4.2 Operational Characteristics

4.2.1 Energy and Resource Requirements

Table 5: Operational comparison

Parameter	Improved ABFR	UASB	Septic Tank
Energy Consumption	0.1 kWh/m³	0.3 kWh/m³	0 kWh/m³
Sludge Production	0.15 g TSS/g COD	0.20 g TSS/g COD	0.25 g TSS/g COD
Temperature Control	Not required	Required	Not required
Startup Time	3-4 weeks	6-8 weeks	Immediate

Advantages of improved ABFR:

- **70% lower energy use** than UASB
- **40% less sludge** than septic tanks
- **Faster startup** than UASB

4.2.2 Maintenance Requirements

- **Media cleaning:** Every 6-12 months (vs. UASB's daily sludge management)
- **No moving parts** (unlike mechanical aerobic systems)
- **pH self-regulation** (unlike anaerobic filters requiring chemical adjustment)

4.3 Economic Analysis

4.3.1 Capital and Operational Costs

Table 6: Cost comparison (USD/m³ capacity)*

Cost Component	Improved ABFR	UASB	Activated Sludge
Construction	$120-150	$200-250	$300-400
Annual O&M	$20-30	$50-70	$80-120
Energy Cost/year	$5-8	$15-20	$50-80

Key economic benefits:

- **40% lower capital costs** than UASB
- **60% lower O&M costs** than activated sludge
- **Payback period:** 3-5 years with biogas utilization

4.4 Application Suitability

4.4.1 Ideal Use Cases

- **Small communities (50-500 PE):** Where UASB is oversized
- **Pre-treatment:** Before constructed wetlands or sand filters
- **Warm climates:** Where temperature >20°C

4.4.2 Limitations vs. Other Systems

- **Not suitable for:**
- High-strength industrial wastewater (UASB better)
- Areas requiring full nutrient removal (aerobic needed)

- Very large scale applications (>1000 m³/day)

4.5 Environmental Impact

4.5.1 Carbon Footprint Comparison

- **Improved ABFR:** 0.25 kg CO_2eq/m³
- **UASB:** 0.40 kg CO_2eq/m³
- **Activated Sludge:** 1.2 kg CO_2eq/m³

The improved ABFR offers:

- **50% lower emissions** than UASB
- **80% reduction** vs. aerobic systems
- **Positive energy balance** when biogas is utilized

4.6 Key Advantages Summary

1. **Best balance** of efficiency and simplicity
2. **Lowest lifecycle costs** among anaerobic options
3. **Most suitable** for decentralized applications
4. **Easiest to operate** with minimal supervision

The analysis illustrates that the better ABFR serves an important role between straightforward septic tanks and complex UASBs for treating wastewater in small homes in developing countries. By making some changes, it corrects the major shortcomings of older atomic beam flight reference systems while also keeping their advantages of using less energy and being simple to use.

5. CONCLUSION

This study shows that a better version of the anaerobic baffle filter reactor can significantly enhance how domestic wastewater is treated in smaller communities. Comparing our findings with standard systems for important factors has helped us reach a number of main outcomes.

5.2 Results

Enhanced ABFR systems reached COD removal of 85-89% and cut TSS by 78-85% which is 20% better than traditional methods. Keeping biomass stable was easier in the hybrid media and the clogging problem common with traditional treatment was eliminated thanks to the new perforated baffle. Compared to typical domestic wastewater, the reactor was able to handle changes in organic loading (0.5-3.0 kg COD/m³/day).

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