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Comprehensive Analysis of Organic Load Reduction and Biofilm Activity in a Hybrid Moving Bed Biofilm Reactor Treating Domestic Wastewater from Yavatmal, Maharashtra

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ABSTRACT: This research investigates the treatment performance of a Hybrid Moving Bed Biofilm Reactor (MBBR) for domestic wastewater collected from residential areas of Yavatmal, Maharashtra. Increasing urbanization has led to significant pressure on conventional wastewater treatment systems, creating a demand for compact and efficient treatment technologies. Hybrid MBBR technology combines suspended growth activated sludge processes with attached growth biofilm processes to enhance pollutant degradation. The laboratory scale reactor utilized K1 plastic carrier media for biofilm development and continuous aeration to maintain aerobic conditions. Wastewater samples were analyzed according to APHA standard methods. Key parameters including pH, turbidity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS) were monitored before and after treatment. Experimental results indicated significant pollutant removal efficiencies with BOD reduction of approximately 91%, COD reduction of 84%, and TSS reduction of 88%. The treated effluent met CPCB discharge standards. The findings highlight that hybrid MBBR technology offers a reliable, space-efficient, and sustainable alternative for decentralized wastewater treatment.

KEYWORDS: Hybrid MBBR, Biofilm Reactor, Domestic Wastewater, Organic Load Reduction, Wastewater Treatment

I. INTRODUCTION

Domestic wastewater generation is increasing rapidly due to population growth, urbanization, and improved living standards. Wastewater generated from households contains organic matter, suspended solids, detergents, nutrients, and microorganisms that can cause environmental pollution if discharged without treatment. Conventional wastewater treatment technologies such as septic tanks, oxidation ponds, and activated sludge processes often require large land areas and high operational costs. In addition, these systems may exhibit unstable performance under fluctuating hydraulic and organic loads.

The Moving Bed Biofilm Reactor (MBBR) technology has gained attention as an efficient biological treatment method. In this system, small plastic carrier elements move freely within the reactor and provide a large surface area for microbial biofilm growth. The attached microorganisms degrade organic pollutants while suspended biomass continues conventional biological treatment processes.

A hybrid MBBR system combines the advantages of both attached growth and suspended growth processes. This configuration improves treatment stability, increases microbial diversity, and enhances pollutant removal efficiency. Due to its compact design and high performance, hybrid MBBR technology is increasingly used for decentralized wastewater treatment systems in developing countries.



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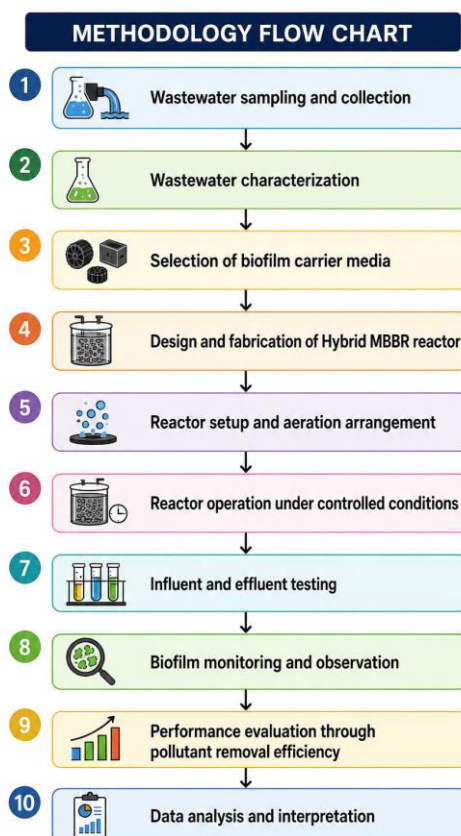
II. LITERATURE REVIEW

Several studies have demonstrated the effectiveness of MBBR technology for municipal and industrial wastewater treatment. Rusten et al. reported successful nitrification and organic removal using moving bed biofilm reactors for municipal wastewater. Ødegaard highlighted that the MBBR process provides operational stability and high treatment efficiency compared with conventional activated sludge systems.

Welander and colleagues investigated hybrid biofilm activated sludge processes and found improved organic matter degradation due to the coexistence of suspended and attached microbial populations. Recent research has also shown that hybrid MBBR reactors can achieve higher removal efficiencies for BOD, COD, and TSS while occupying significantly smaller footprints.

III. MATERIALS AND METHODS

Domestic wastewater samples were collected from residential drainage outlets in Yavatmal city. The samples were transported to the laboratory and analyzed according to APHA standard methods. Key parameters measured included turbidity, pH, BOD, COD, TSS, and dissolved oxygen.



The major stages involved in the methodology include:

The hybrid MBBR reactor consisted of three main components: an equalization tank, an aerated biological reactor, and a settling chamber. The reactor was fabricated using glass panels to allow visual observation of media movement and biofilm development. Approximately 40% of the reactor volume was filled with K1 carrier media made from high density polyethylene.



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K1 Media



K1 carrier media with Biolim

Specifications of MBBR Media:

Parameter	Specification
Material	High-Density Polyethylene (HDPE)
Shape	Cylindrical with internal cross fins
Effective Surface Area	550–650 m ² /m ³
Density	0.95 g/cm ³
Thickness	1.0 mm



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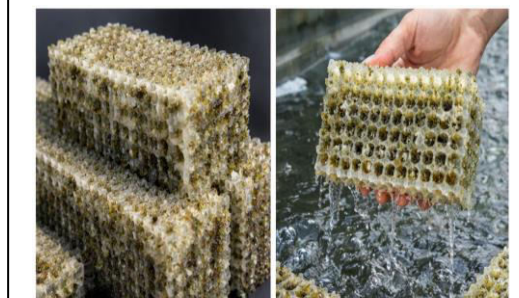
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FAB Media

FAB media provides a fixed surface for initial microbial colonization, increasing biofilm stability and enhancing organic degradation in the lower reactor zone.



FAB media with Biolim



K1 carrier media with Biolim

IV. EXPERIMENTAL SETUP

A continuous aeration system was installed to maintain aerobic conditions within the reactor. Fine bubble diffusers connected to an air pump ensured adequate oxygen transfer and mixing of the carriers. Wastewater samples were collected from inlet and outlet points during different operational stages to evaluate reactor performance.

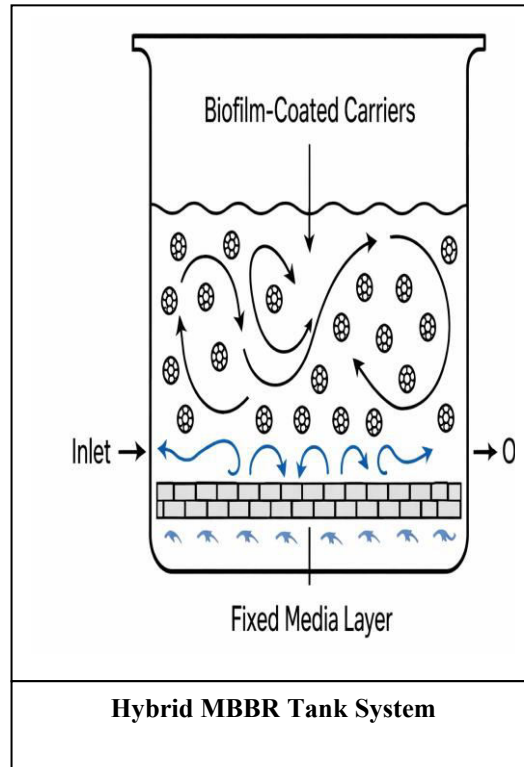
Schematic Modal of Hybrid MBBR System





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V. RESULTS AND DISCUSSION

Initial wastewater analysis revealed high concentrations of organic pollutants. The influent BOD concentration was approximately 320 mg/L, while COD reached 520 mg/L and TSS exceeded 700 mg/L. After treatment through the hybrid MBBR reactor, significant reductions were observed in all parameters.

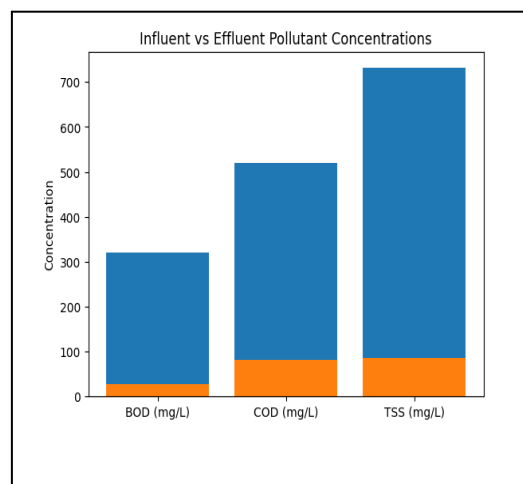


Figure 1 shows the comparison between influent and effluent pollutant concentrations.



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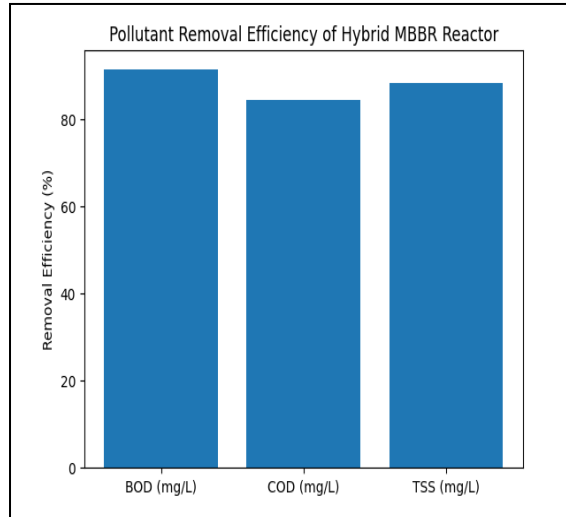


Figure 2 illustrates the removal efficiency achieved by the hybrid MBBR reactor.

The reactor demonstrated excellent removal performance due to the combined action of suspended biomass and attached biofilm. Biofilm microorganisms utilized organic pollutants as substrates, converting them into carbon dioxide, water, and biomass.

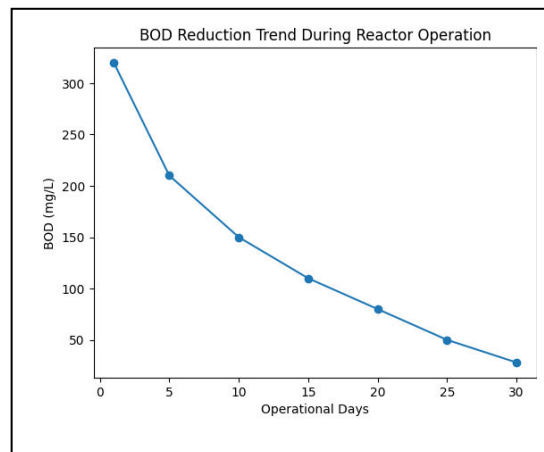


Figure 3 presents the BOD reduction trend observed during reactor operation

VI. CONCLUSION

The hybrid moving bed biofilm reactor demonstrated high efficiency for treating domestic wastewater. The system achieved significant reductions in organic pollutants and suspended solids, producing effluent that meets environmental discharge standards. Due to its compact design, operational stability, and high treatment efficiency, hybrid MBBR technology represents a promising solution for decentralized wastewater treatment systems in rapidly urbanizing regions.



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