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Abstract

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Ke ords: Microbial Fuel Cells; Industrial e uents; Energy generation; Electrode materials; Scaling up; Wastewater treatment; Technological challenges

Introduction

Microbial Fuel Cells (MFCs) have garnered signi cant attention in recent years due to their dual capability of treating industrial e uents while generating renewable energy. is innovative technology harnesses the metabolic processes of microorganisms to convert organic matter directly into electricity, o ering a sustainable alternative to traditional wastewater treatment methods [1,2]. Originally conceived as a bioelectrochemical system for energy production, MFCs have evolved through advancements in electrode materials, microbial engineering, and system design, enabling their application in diverse industrial settings. is article provides a comprehensive overview of the fundamental principles underlying MFC operation, recent technological progress, and the challenges associated with scaling up these systems for industrial applications. Furthermore, it explores the wide-ranging applications of MFCs in treating industrial e uents, highlighting their potential to mitigate environmental pollution and contribute to renewable energy production [3,4]. Despite these advancements, several obstacles such as electrode scalability, bio lm management, and long-term operational stability hinder widespread implementation of MFCs in industrial contexts. By examining the current state of MFC technology and discussing potential solutions to existing challenges, this review aims to underscore the transformative potential of MFCs in advancing sustainable industrial practices and vast amounts of organic-rich wastewater containing pollutants that can be challenging to degrade using traditional methods. MFCs o er a sustainable alternative by simultaneously treating wastewater and generating electricity. Key bene ts include

Bioremediation: MFCs promote the degradation of organic pollutants through microbial metabolism, reducing chemical oxygen demand (COD) and removing contaminants.

Energ reco er : Electricity generated from MFCs can be used to power onsite equipment or fed back into the grid, o setting energy costs and reducing carbon footprints.

Cost e cienc : While initial setup costs can be signi cant, operational savings over time, coupled with potential revenue from electricity sales, make MFCs economically viable in the long run.

Scaling up challenges

Despite the promising developments, scaling up MFC technology for industrial applications presents several challenges

Electrode scaling: Maintaining efficient electron transfer over larger electrode surfaces without compromising performance remains a challenge.

Bio lm management: Controlling and optimizing the microbial bio lm on electrode surfaces to ensure stable and predictable performance.

Long-term stabilit : Ensuring MFCs operate reliably over extended periods without signi cant drop in performance or microbial activity.

Integration with Existing Infrastructure: Adapting MFC systems to t within existing industrial wastewater treatment processes and infrastructure.

Conclusion

Microbial Fuel Cells (MFCs) represent a promising technology at the intersection of environmental remediation and renewable energy generation. roughout this review, we have explored the fundamental principles of MFC operation, highlighted recent advancements in technology, discussed their applications in industrial e uent treatment, and identi ed key challenges associated with scaling up and widespread adoption. Advancements in electrode materials, microbial consortia engineering, and system integration have signi cantly improved MFC performance, making them increasingly viable for industrial applications. MFCs o er a dual bene t of treating organic-rich industrial e uents while generating electricity, thereby promoting sustainable practices and reducing environmental impact. Looking forward, the future of MFCs hinges on overcoming these obstacles to realize their full potential in industrial settings. Collaborative e orts between researchers, engineers, and industry stakeholders will be essential in advancing MFC technology, optimizing system performance, and integrating these systems into existing industrial infrastructure.

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