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Microbial Fuel Cells' Integration in Constructed Wetlands: A Mini-Review

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INTRODUCTION

Constructed wetlands (CWs) are sustainable wastewater treatment systems leveraging natural processes to remove pollutants. Microbial fuel cells (MFCs) enhance CWs by converting organic matter into bioelectricity via electroactive bacteria [1]. Integrating MFCs with CWs creates hybrid systems that improve treatment efficiency and generate renewable energy. The CW-MFC's performance factors include design setup, water quality, electrochemical conditions, microbial activity, plant type, and environmental parameters. The synergy between CWs and MFCs aligns with circular economy goals, offering decentralized solutions for water and energy sustainability. This review aims to establish a foundation for advancing CW-MFC systems in sustainable wastewater treatment and resource recovery.

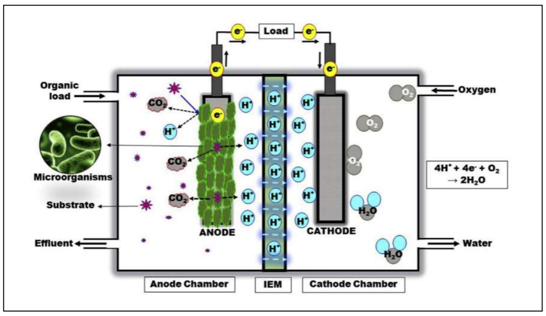

Fig. 1. Working principle of MFC [2]

MATERIALS & METHODS

- **Database search**: ScienceDirect, PubMed, Scopus, Web of Science.
- **Keywords**: "microbial fuel cells," "constructed wetlands," "wastewater treatment," "energy recovery."
- **Initial records**: 16,431 → filtered (2020–2025, Environmental Science/Energy/Engineering) → **3,448 articles**.
- **Refined search**: 131 relevant articles → screened by title/abstract.
- **Final selection**: Full-text review of high-citation studies on CW-MFC integration, performance, and experimental data

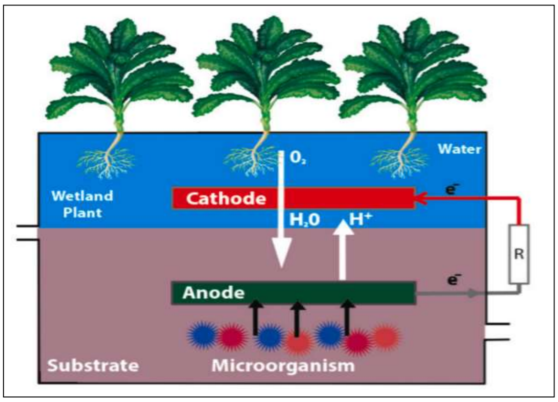

Fig. 2 Schematic diagram of CW-MFC [3]

RESULTS & DISCUSSION

- CW-MFCs demonstrate synergistic benefits [2],[3]:
  - **Treatment efficiency**: >90% COD (chemical oxygen demand) removal, 91% phosphorus, and 99% nitrogen reduction.
  - **Energy recovery**: Power densities of 6–6119 mW/m², suitable for low-energy devices.
- **Mechanisms**: Electroactive bacteria (*Geobacter*, *Shewanella*) drive bioelectricity, while vegetation enhances oxygenation and supports biofilm for degradation.
- **Challenges:** Low power output, electrode fouling, and scaling difficulties. Optimizations like stacked MFCs and carbon-based electrodes improve performance. Field studies confirm feasibility, but long-term stability and cost-effective materials remain critical for widespread adoption.

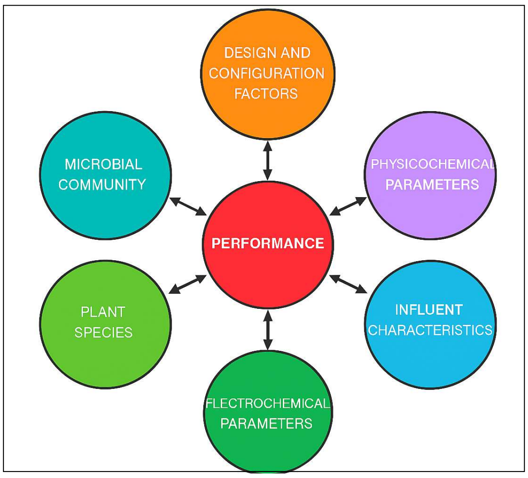

Fig. 3 Major factors affecting CW-MFC's performance

CONCLUSION

CW-MFC systems combine sustainable wastewater treatment with renewable energy generation, achieving high pollutant removal and modest power output. Overcoming key barriers—such as low energy yields, electrode fouling, and scalability—requires innovation in materials and hybrid designs (e.g., solar integration) to complement output power. Future efforts should focus on long-term field trials, standardized evaluation, and socioeconomic viability. CW-MFCs hold strong potential as decentralized solutions aligned with SDGs 6, 11, and 13.

REFERENCES

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[2] https://doi.org/10.1016/j.jclepro.2019.02.172
[3] https://doi.org/10.1016/j.jwpe.2024.105592

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