Electricity Generation from Anaerobic Wastewater Treatment in Microbial Fuel Cells

Wastewater treatment is an energy intensive process to remove contaminants and protect the environment. While some wastewater treatment plants (WWTPs) recover a small portion of their energy demand, usually through energy recovery from solids processes, most of the useful energy available from wastewater remains unrecovered. Microbial Fuel Cells (MFCs) operate by utilizing exoelectrogenic microorganisms (those which have the ability to transfer electrons outside of the cell) to transfer electrons from an electron donor in an influent feed to an insoluble electron acceptor (the anode). This WERF study tested anaerobic microbial fuel cell treatment of domestic wastewater and produced sustainable electricity at the pilot scale using a novel MFC system in a multiple anode/cathode granular activated carbon configuration (MAC-GACMFC), effectively integrating multiple MFCs into a single unit.

Four pilot-scale MAC-GACMFC systems in the test trailer at the Gloversville-Johnstown wastewater treatment plant.

The unique advantage of this new configuration is that it can increase power generation at low cost in a smaller space. MAC-GACMFC involves fundamental mechanisms of microbiology (e.g., biofilm growth on granular activated carbon, GAC, particles), biochemistry (e.g., COD removal inside biofilms), and electrochemistry (e.g., electron generation and transfer on anodes and cathodes), which make it truly challenging to achieve desirable power generation simultaneously with effective wastewater treatment. Figure 1 depicts MFC process mechanisms.

The researchers operated four pilot-scale, 16-L MAC-GACMFC systems at the Gloversville-Johnstown Joint Wastewater Treatment Facility in Johnstown, NY, over a six-month period,

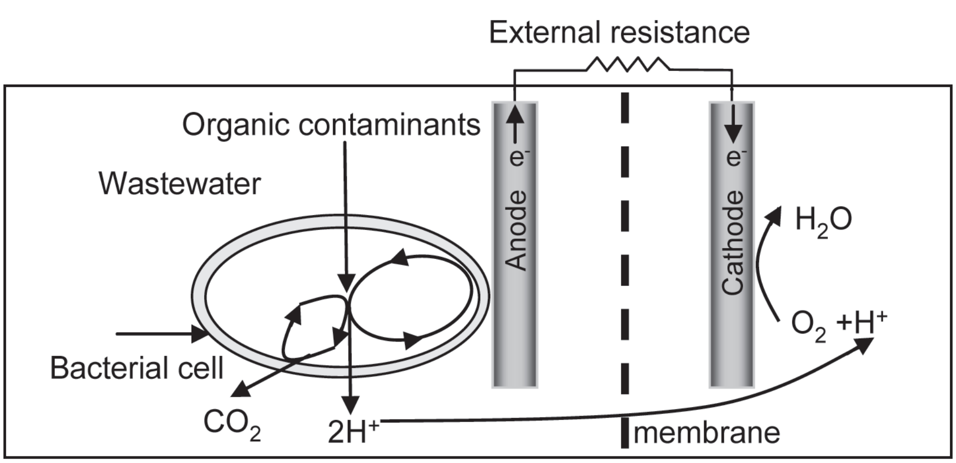

Figure 1. Schematic depicting the oxidation of contaminants in wastewater and the electrical output in an MFC.

BENEFITS

- Demonstrates a pilot-scale (16 L) microbial fuel cell with 920 mW/m^2 power density utilizing anaerobic sludge electrogenic bacteria in a Granular Activated Carbon (GAC) bed (anode) and a low-cost MnO_2 cathode.
- Demonstrates that multi-anode/cathode GAC-MFC (both 2-anode/cathode and 4-anode/cathode) enhances power generation over single anode/cathode configurations.
- Demonstrates MFCs producing electricity using domestic wastewater.
- Provides insights into future design, operations, and optimization of MFCs.

RELATED PRODUCTS

Development of a Microbial Fuel Cell for Sustainable Wastewater Treatment (U1R06)

Energy Efficiency in Wastewater Treatment in North America: A Compendium of Best Practices and Case Studies of Novel Approaches (OWSO4R07e)

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testing organic loading rates and hydraulic retention times (HRT). The MAC-GACMFC systems achieved good anaerobic wastewater treatment efficiency with COD removals greater than 80%, and effective power densities on the order of 300 mW/m^3 in a single cathode configuration. In addition, a new, cost-effective catalyst, manganese dioxide (MnO_2) developed by the University of Connecticut, was applied in the pilot-scale MFC systems. The results showed that the MnO_2 catalyst achieves the same power generation as the more costly platinum catalyst that has been used to date in other MFCs.

This study also demonstrated that multi-cathode MFCs can generate more power than single-cathode MFCs. For instance, the power generation of a 2-anode/cathode MFC was twice that of a single-anode/cathode MFC. Also, the power generation of 4-anode/cathode MFC was 3.5 times that of a single-anode-cathode MFC. In addition, the 4-anode/cathode MFCs can still generate desirable power at high COD (>3000 mg/L), while the single-anode/cathode MFCs leveled off at COD higher than 1000 mg/L. This clearly reveals the effectiveness of multi-anode/cathode MFCs in terms of power generation and wastewater treatment.

Table 1. The Internal Resistance (R_{in}) and Power Density (mW/m^3) of Single-Electrode GAC-MFCs and Multi-Anode/Cathode GAC-MFCs.

	Single-Electrode GAC-MFC	2-Anode/Cathode GAC-MFC	4-Anode/Cathode GAC-MFC
Internal Resistance (R_{in}, ohm)	140 ± 15	103 ± 15	63 ± 10
Power Density (mW/m^3)	350 ± 20	550 ± 30	920 ± 35
Power Density per Anode/Cathode Pair (mW/m^3)	350 ± 20	275 ± 30	306 ± 35

Study Conclusions

- MAC-GACMFC is a promising microbial fuel cell configuration that integrates multiple fuel cells into a single unit. The system achieves excellent wastewater treatment efficiency and produces power when treating actual domestic wastewater.
- By growing biofilms on GAC particles, MAC-GACMFCs improve power generation.
- Operational parameters, COD and HRT, affect MFC performance. Sufficient time is needed for contact between biofilms and substrates.
- Oxygen reduction at the cathode limits the power generation. Electrode numbers, instead of electrode areas, improve power generation. Therefore, MAC-GACMFC substantially increases power generation when compared with single-anode/cathode MFC.
- MnO_2 catalyst demonstrated good power generation and efficient wastewater treatment, and reveals great promise for replacing platinum.
- MAC-GACMFC has the potential to be applied in wastewater treatment plants to achieve self-sustainable treatment processes, but improvements should be identified through future research to enhance power conversion efficiency and ensure stable operation.

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