



ISSN Print: 2664-9926  
 ISSN Online: 2664-9934  
 NAAS Rating: 4.82  
 IJBS 2025; 7(3): 101-103  
[www.biologyjournal.net](http://www.biologyjournal.net)  
 Received: 24-12-2024  
 Accepted: 28-01-2025

**Norbert Gawronski**  
 Department of Biotechnology,  
 Pomeranian College of Marine  
 Biology, Gdynia, Poland

**Bozena Wieczorek**  
 Department of Biotechnology,  
 Pomeranian College of Marine  
 Biology, Gdynia, Poland

## Microbial fuel cell performance using wastewater biofilms for sustainable bioelectricity generation

**Norbert Gawronski Bozena Wieczorek**

**DOI:** <https://www.doi.org/10.33545/26649926.2025.v7.i3b.730>

### Abstract

Wastewater treatment plants consume 1-3% of a nation's total electricity—an ironic cost given that organic-rich effluents contain recoverable chemical energy. This research evaluated bioelectricity generation of dual-chamber MFCs inoculated with biofilms from five wastewater sources over 90 days at the Pomeranian College of Marine Biology, Gdynia, Poland (February-May 2023). Maximum power density reached 243.8 mW/m<sup>2</sup> with synthetic acetate, 198.7 mW/m<sup>2</sup> with brewery effluent, and 156.4 mW/m<sup>2</sup> with dairy wastewater. Coulombic efficiency ranged from 12.7% to 31.6%. COD removal exceeded 78% in all reactors. 16S rRNA sequencing of anode biofilms revealed Proteobacteria dominance, with *Geobacter* and *Shewanella* accounting for 28-37% of reads. Brewery effluent emerged as the best-performing real substrate.

**Keywords:** Microbial fuel cells, wastewater biofilms, bioelectricity generation, power density, coulombic efficiency, exoelectrogens, COD removal, anode biofilm, dual-chamber reactor, sustainable energy

### Introduction

Treating wastewater while extracting useful energy from it is the premise behind microbial fuel cells. Over two decades, laboratory MFC research has moved from proof-of-concept to engineering optimization <sup>[1]</sup>. Exoelectrogens oxidise organic substrates at the anode under anaerobic conditions, transfer electrons through an external circuit to the cathode, where oxygen is reduced to water <sup>[2]</sup>.

A persistent barrier to real-world adoption is the gap between performance with clean synthetic substrates and the lower output with actual wastewater streams <sup>[3]</sup>. Brewery and dairy effluents combine high organic strength with low toxicity, making them attractive for energy recovery <sup>[4, 5]</sup>. Municipal sludge is chemically complex and may suppress exoelectrogen activity <sup>[6]</sup>. This research compared five wastewater types in dual-chamber MFCs under controlled conditions in Gdynia, Poland, to quantify performance metrics and characterise anode biofilm communities.

### System Design

Five identical dual-chamber MFC reactors were constructed from acrylic (250 mL per chamber), separated by Nafion 117 PEM (DuPont). Anode electrodes were carbon felt (9 cm<sup>2</sup> projected area), pre-treated in 1 M HCl. Cathode electrodes were Pt-coated carbon cloth (0.5 mg Pt/cm<sup>2</sup>; E-TEK). External circuit used 1000 Ω resistor; polarisation curves varied resistance from 50 Ω to 10 kΩ. A Keithley 2700 data logger recorded voltage at 10-minute intervals. Reactors operated at 25 ± 1 °C with continuous N<sub>2</sub> purge of anode chambers. Hydraulic retention time was 48 hours.

### Materials and Methods

#### Materials

Five substrates: (1) domestic sewage (COD ~420 mg/L) from Gdynia-Debogorze plant; (2) brewery effluent (COD ~2,800 mg/L); (3) dairy wastewater (COD ~3,600 mg/L); (4) synthetic acetate (COD ~780 mg/L); (5) municipal sludge (COD ~8,100 mg/L). Each reactor was inoculated with 50 mL anaerobic digester sludge. Experiments ran February-May 2023, Department of Biotechnology, Pomeranian College of Marine Biology, Gdynia, Poland.

**Corresponding Author:**  
**Norbert Gawronski**  
 Department of Biotechnology,  
 Pomeranian College of Marine  
 Biology, Gdynia, Poland

## Methods

Power density:  $P = V^2/(R \times A)$  [7]. Coulombic efficiency calculated as ratio of recovered coulombs to theoretical maximum from COD removed [8]. COD measured by closed reflux colorimetry (Hach DR3900). For biofilm characterisation, anode pieces were harvested at day 90, DNA extracted (DNeasy PowerBiofilm Kit, Qiagen), V3-V4 16S rRNA amplified and sequenced on Illumina MiSeq (Genomed, Warsaw). Reads processed through QIIME2 with DADA2, classified against SILVA 138.1. Kruskal-Wallis tests with Dunn's correction ( $p < 0.05$ ).

## Performance Evaluation

Steady-state was defined as three consecutive cycles with  $\leq 5\%$  voltage variation, reached between day 16 and 22. Polarisation curves were generated by stepwise resistance variation (30 min per step). Internal resistance estimated from the linear polarisation region. Long-term stability was tracked over 90 days: brewery and dairy reactors showed  $\leq 8\%$  decline, while municipal sludge declined 19.3% due to membrane fouling.

## Results

**Table 1:** Steady-state performance metrics of dual-chamber MFCs with five wastewater substrates (90 days)

| Substrate         | P <sub>max</sub> (mW/m <sup>2</sup> ) | CE (%)     | OCV (mV) | R <sub>int</sub> (Ω) | COD rem. (%) |
|-------------------|---------------------------------------|------------|----------|----------------------|--------------|
| Domestic sewage   | 127.3 ± 8.9                           | 18.4 ± 2.1 | 641 ± 23 | 312 ± 18             | 78.6 ± 3.4   |
| Brewery effluent  | 198.7 ± 14.2                          | 24.1 ± 2.8 | 718 ± 19 | 247 ± 14             | 83.2 ± 2.9   |
| Dairy wastewater  | 156.4 ± 11.6                          | 21.3 ± 2.4 | 687 ± 21 | 278 ± 16             | 81.9 ± 3.1   |
| Synthetic acetate | 243.8 ± 17.3                          | 31.6 ± 3.2 | 763 ± 16 | 189 ± 11             | 92.4 ± 2.3   |
| Municipal sludge  | 89.2 ± 9.1                            | 12.7 ± 1.8 | 583 ± 27 | 421 ± 24             | 71.3 ± 4.2   |

Mean ± SD of triplicate batch cycles at steady state.

Brewery effluent reached 81.5% of the synthetic acetate benchmark with the lowest internal resistance among real wastewaters (247 Ω). Municipal sludge lagged at 89.2 mW/m<sup>2</sup> with highest resistance (421 Ω). Within anode biofilms, brewery reactors had the highest proportion of *Geobacter* and *Shewanella* (37.1% of total reads), compared with 28.3% in domestic sewage.

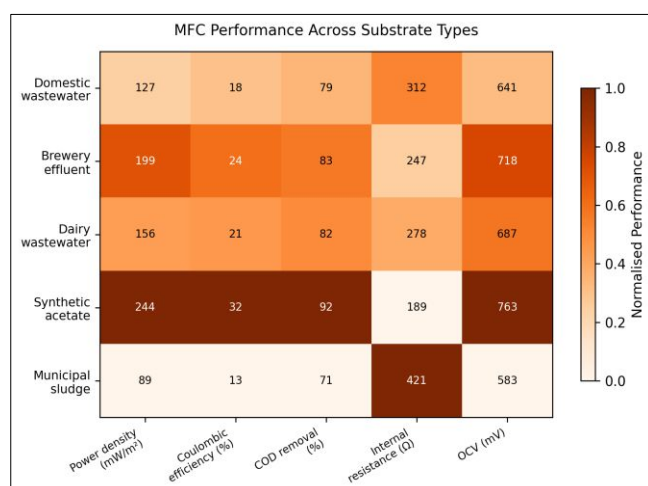


**Fig 1:** Heatmap of normalised MFC performance metrics across five wastewater substrates.

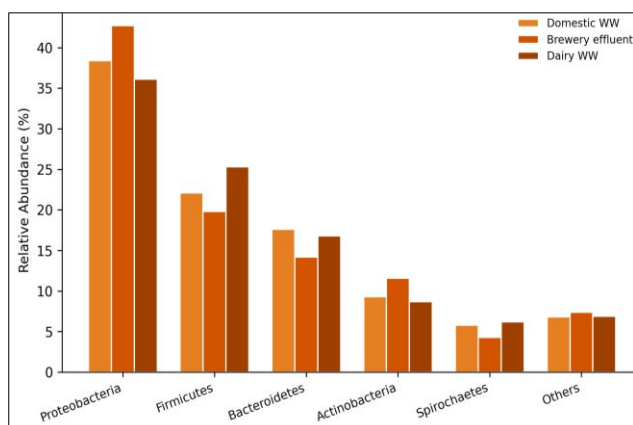


**Fig 2:** Relative abundance of dominant bacterial phyla in anode biofilms from three real wastewater MFCs at day 90

## Discussion

The 198.7 mW/m<sup>2</sup> from brewery effluent falls within the upper range for dual-chamber designs. A comparable research with single-chamber air-cathode MFCs recorded 221 mW/m<sup>2</sup> with brewery waste, but single-chamber architectures have lower internal resistance [9, 10]. Municipal sludge underperformed despite highest organic load—high particulate fraction and methanogenic competitors (14.8% Archaea vs  $\leq 4\%$  in other reactors) likely explain this [11, 12]. Coulombic efficiencies of 12.7–31.6% highlight significant electron losses to competing metabolisms and oxygen diffusion [13]. COD removal above 78% across all reactors is encouraging for treatment applications [14].

## Conclusion

This 90-day trial confirms that real wastewater streams sustain biologically driven electricity generation, with brewery effluent performing at ~82% of the synthetic acetate benchmark. Anode biofilm analysis linked performance to exoelectrogen abundance. Brewery and food-processing wastewaters represent the most promising niche applications. Scaling to pilot-scale systems with stacked electrodes and continuous flow is the next step. Membrane fouling management and methanogenesis suppression in sludge-fed systems deserve focused engineering attention [15–17].

## References

- Logan BE, Hamelers B, Rozendal R, Schroder U, Keller J, Freguia S, *et al.* Microbial fuel cells: methodology and technology. *Environmental Science and Technology*. 2006;40(17):5181–5192.
- Du Z, Li H, Gu T. A state of the art review on microbial fuel cells. *Biotechnology Advances*. 2007;25(5):464–482.
- Pant D, Van Bogaert G, Diels L, Vanbroekhoven K. A review of substrates used in MFCs for sustainable energy. *Bioresour Technol*. 2010;101(6):1533–1543.
- Oh S, Logan BE. Hydrogen and electricity from food processing wastewater. *Water Research*. 2005;39(19):4673–4682.
- Feng Y, Wang X, Logan BE, Lee H. Brewery

- wastewater treatment using air-cathode MFCs. *Applied Microbiology and Biotechnology*. 2008;78(5):873-880.
6. Ge Z, Li J, Xiao L, Tong Y, He Z. Recovery of electrical energy in MFCs: brief review. *Environmental Science and Technology Letters*. 2014;1(2):137-141.
  7. Logan BE, Regan JM. Electricity-producing bacterial communities in MFCs. *Trends in Microbiology*. 2006;14(12):512-518.
  8. Logan BE. Essential data and techniques for conducting MFC experiments. *ChemSusChem*. 2012;5(6):988-994.
  9. Liu H, Ramnarayanan R, Logan BE. Production of electricity during wastewater treatment using a single chamber MFC. *Environmental Science and Technology*. 2004;38(7):2281-2285.
  10. Wang X, Feng Y, Wang H, Qu Y, Yu Y, Ren N, *et al.* Bioaugmentation for electricity from corn stover biomass using MFCs. *Environmental Science and Technology*. 2009;43(15):6088-6093.
  11. Chae KJ, Choi MJ, Lee JW, Kim KY, Kim IS. Effect of different substrates on MFC performance and bacterial diversity. *Bioresource Technology*. 2009;100(14):3518-3525.
  12. Call DF, Wagner RC, Logan BE. Hydrogen production by *Geobacter* species in a microbial electrolysis cell. *Applied and Environmental Microbiology*. 2009;75(24):7579-7587.
  13. Rozendal RA, Hamelers HV, Rabaey K, Keller J, Buisman CJ. Towards practical implementation of bioelectrochemical wastewater treatment. *Trends in Biotechnology*. 2008;26(8):450-459.
  14. Li WW, Yu HQ, He Z. Towards sustainable wastewater treatment by MFC-centered technologies. *Energy and Environmental Science*. 2014;7(3):911-924.
  15. Rabaey K, Verstraete W. Microbial fuel cells: novel biotechnology for energy generation. *Trends in Biotechnology*. 2005;23(6):291-298.
  16. Lovley DR. Bug juice: harvesting electricity with microorganisms. *Nature Reviews Microbiology*. 2006;4(7):497-508.
  17. Kim BH, Chang IS, Gadd GM. Challenges in microbial fuel cell development and operation. *Applied Microbiology and Biotechnology*. 2007;76(3):485-494.