Evaluation of Microbial Fuel Cell and Microbial Electrolysis Cell for the Treatment of Refractory Dissolved Organic Matter in Swine Wastewater

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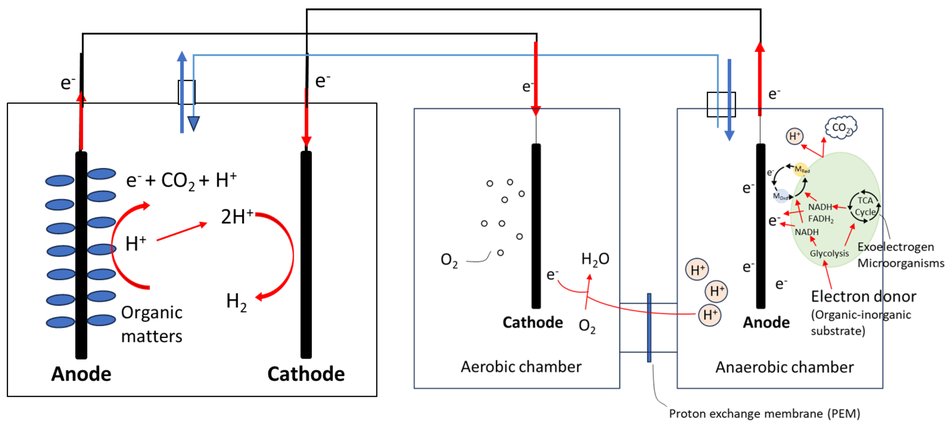
Introduction

The organic content in swine wastewater remains high and hard to biodegrade even after conventional treatment. Using microbial electrochemical technologies, organics can be converted into electrons and hydrogen through electrochemical reactions, achieving removal and energy recovery. Therefore, this study employed MFC and MEC systems in stepwise experiments to determine optimal operating conditions.



MEC system

Anode: Organic matters → $CO_2 + H^+ + e^-$

Cathode: $H^+ + 2e^- \rightarrow H_2$

MFC system

Anode: $CH_3COO^- + 2H_2O \rightarrow 2CO_2 + 7H^+ + 8e^-$

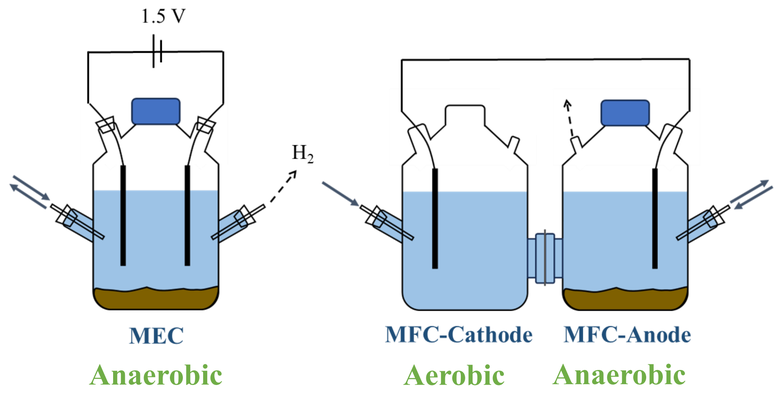
$C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + 24H^+ + 24e^-$

Cathode: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

Fig 1. Reactions in the MEC and MFC system (Koul, Devda et al. 2022; Ucar, Zhang et al. 2017)

Material and Method

The reactor was inoculated with swine wastewater sludge and fed with the effluent from an anaerobic fluidized bed membrane bioreactor (AMFBR), which contained 1700-2100 mg COD/L, 1500 mg NH_3-N/L, and 50-200 mg P/L. The batch test was conducted for about one month without influent or effluent flow, sampling every two days.



- ✓ 300 mL sludge + 500 mL anaerobic effluent
- ✓ Electrode: carbon rod
- ✓ Proton exchange membrane (Nafion N117)
- ✓ Buffer solution
  - 6 mL NaCl (50 g/L)
  - 0.72 mL $MgSO_4$ (10 g/L)
  - 4 mL $CaCl_2$ (100g/L)

Fig 2. The scheme of MEC and MFC system

Research Objective

1. Reduce COD concentration in water to meet discharge standards.
2. Degrade difficult-to-decompose soluble organic matter (DOM), such as humic acid.
3. Cultivate electrogenic bacteria to perform electrochemical reactions.

Result and Discussion

Performance of MFC and MEC system (Batch Test)

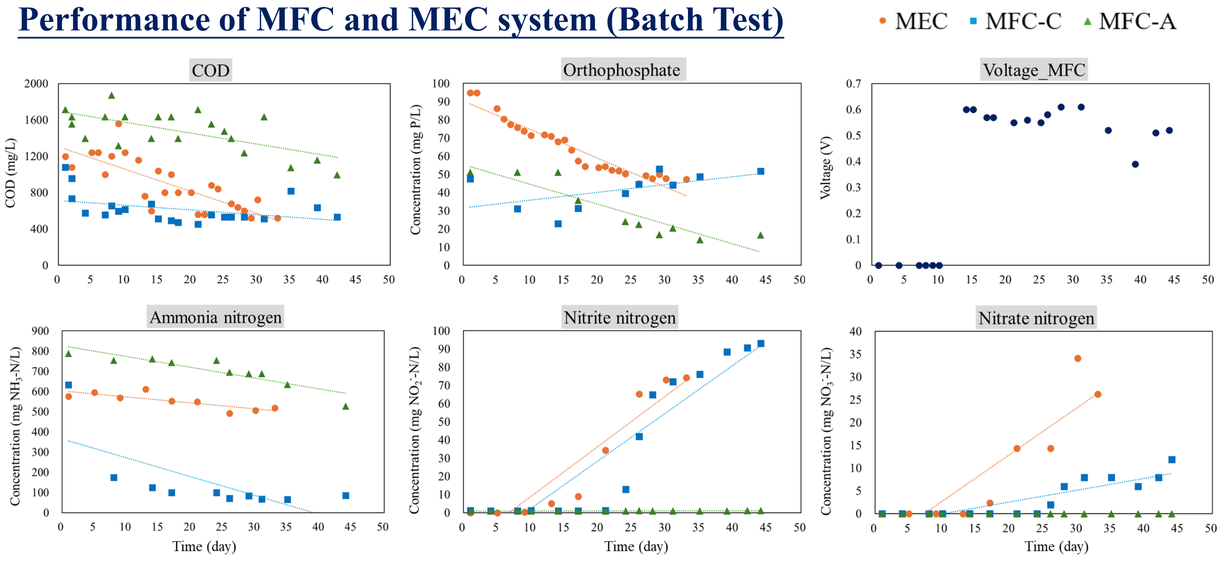


Fig 3. Water quality analysis and output voltage of reaction system

- ✓ Under optimal conditions, the system achieved removal efficiencies of 56.5% for COD, 12% for ammonia nitrogen, and 50.5% for orthophosphate.
- ✓ Swine wastewater contains a portion of biodegradable organic matter. The use of MFC and MEC systems can enhance organic matter removal; however, the presence of refractory compounds may still limit overall treatment efficiency.

Evaluation of bacterial growth in the reactor

At the family level, the dominant group is f_*Clostridiaceae*, a hydrogen-producing microorganism that can degrade humic acid anaerobically. The target community f_*Geobacteraceae*, detected at the MFC anode, can anaerobically oxidize aromatic hydrocarbon compounds and improve electrochemical performance. At the genus level, it was also found, supporting its potential in humic acid degradation and electricity generation.

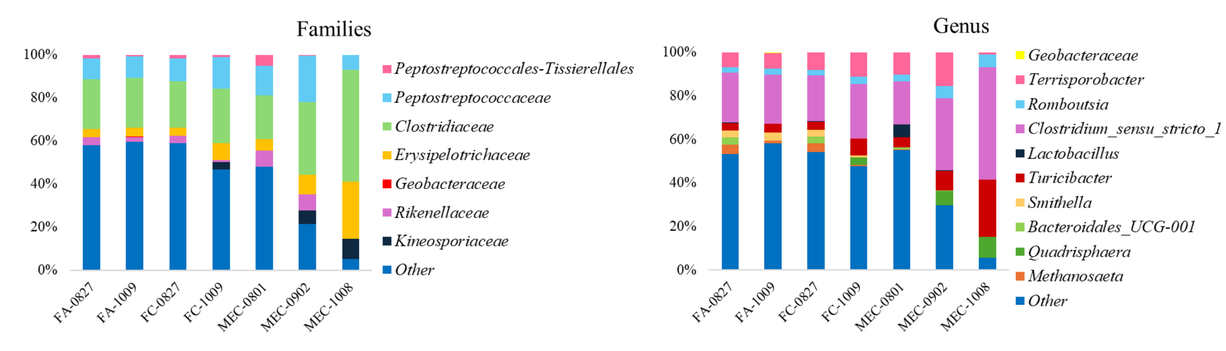


Fig 4. NGS gene sequencing results at the Families and Genus levels

FEEM and UV-vis absorption spectroscopy

Table 1. UV-vis spectroscopy results

Day	254 nm	280 nm	400 nm	E254/E280	E254/E400
2	4.05	3.40	0.70	1.19	5.79
9	7.30	5.55	0.60	1.32	12.17
16	7.15	5.25	0.65	1.36	11.00
23	7.30	5.00	0.50	1.46	14.60
30	7.05	4.90	0.55	1.44	12.82

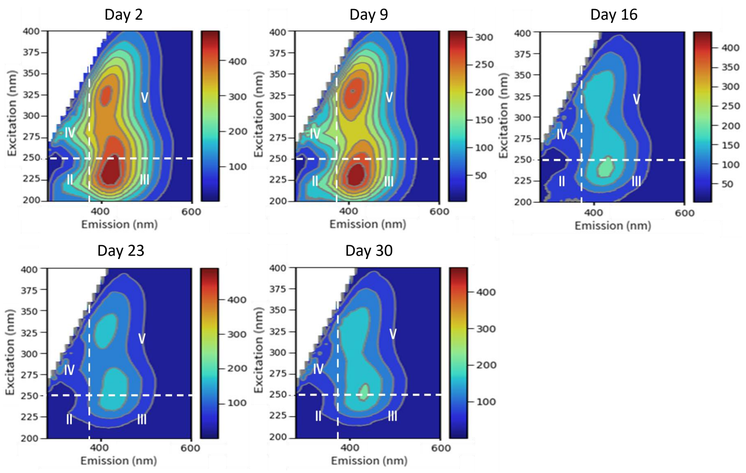


Fig 5. FEEM- humic acid results

Both aromaticity and molecular weight of humic substances decreased, which may be attributed to the cleavage of aromatic rings or the breakdown of macromolecules into smaller ones.

The FEEM results revealed variations in humic acid. From Day 2 to 9, strong signals appeared in Regions III and V, corresponding to humic-like and fulvic-like substances. From Day 16 to 30, these signals weakened, indicating effective humic acid degradation by the system.

Performance of MFC-MEC system (Series test)

50 mL of effluent was collected from the MFC-C and introduced into the MEC reactor and then add 50 mL of the mixed wastewater into the MFC-C system.

- Sampling every four days in a continuous flow manner.
- Mixed wastewater =wastewater : glucose solution = 1 : 4

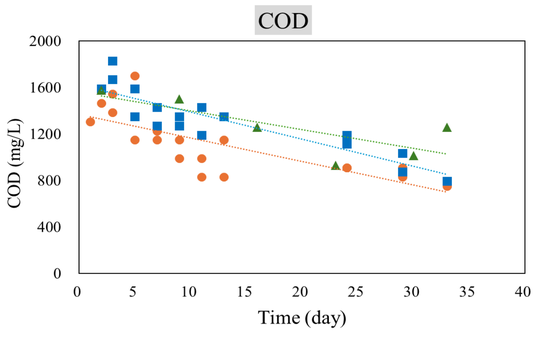


Fig 6. COD concentration of MFC-MEC system

- ✓ MFC and MEC systems can reduce COD from 1500 mg/L to about 800 mg/L, achieving a certain degree of COD removal rate (more than 40%), and have the potential to degrade organic matter.

Conclusion

- Compared to traditional anaerobic treatment, MFC and MEC can reduce the COD from 2000 mg/L to 600 mg/L which meet discharge standards and generating electricity.
- The presence of *Geobacteraceae* bacteria was observed from NGS gene sequencing analysis, and it is inferred that the system can perform electrochemical reactions and, through synergistic reactions with other bacteria, to process aromatic hydrocarbon compounds such as humic acid.
- UV–vis absorption spectroscopy and FEEM analysis revealed a reduction in humic substances originally present in swine wastewater after treatment with the system, indicating that these substances were broken down from macromolecules into smaller molecular forms, or their functional groups and aromatic structures were disrupted.

Future work

- The experiment will be conducted using simulated wastewater and adding other trace elements to test and improve the performance of the MFC-MEC system after the series connection.
- The system operation time will be extended, and the treatment effect will be further analyzed after the system performance is more stable to obtain the best operating conditions.