Electricity Generation and Industrial Wastewater Treatment Using Microbial Fuel Cell

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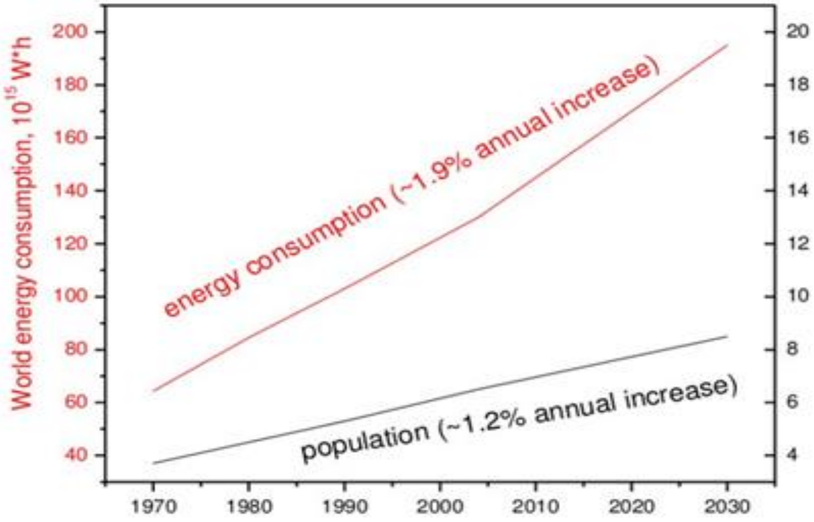
Overview

- Introduction
- Aims and Objectives
- Materials and Methodology
- Results
- Conclusion & Recommendation

Introduction

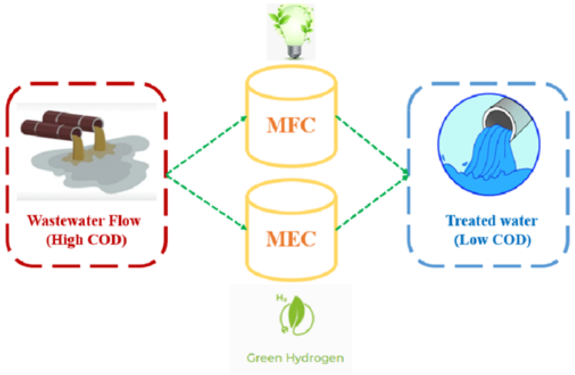
- Humanity creates about 380 billion liters of wastewater annually, and the volume is expected to increase 24% by 2030 and 51% by 2050.
- Treating municipal wastewater represents 3-5% of the global electricity consumption.
- Wastewater treatment plants consume approximately **0.5–2.0 kWh per cubic meter** of treated water (Hamawand, 2023).



Dimitriev (2013)

- Energy in wastewater: Chemical energy, Thermal Energy, and Kinetic Energy.
- The organic energy in wastewater is approximately **5-10 times greater** than the electric energy required to treat it (Horne et al. 2013; Moss et al. 2013).
- 16.1-kilo Joules of Energy for each gram of COD **(2.8–4.2 kWh/kg COD)**

- **Microbial Fuel Cells (MFCs)** can convert chemical energy into electrical energy through the use of microbes.
- These microorganisms act as biocatalysts to oxidize the chemical components of the biodegradable substrates using the electrodes in the MFC.
- The chemical energy of wastewater accumulates in chemical compounds and may be extracted through the oxidation–reduction reactions of these substances.



Aims & Objectives

- The main aim of this paper is to investigate treatment efficiency and energy generation from various industrial wastewater streams using tubular pilot scale MFCs.
- The study’s specific objectives were:
    1. To design pilot scale tubular MFCs.
    2. To assess the efficiency of MFC in treating industrial wastewater.
    3. To evaluate energy generation from different industrial wastewater using MFCs.

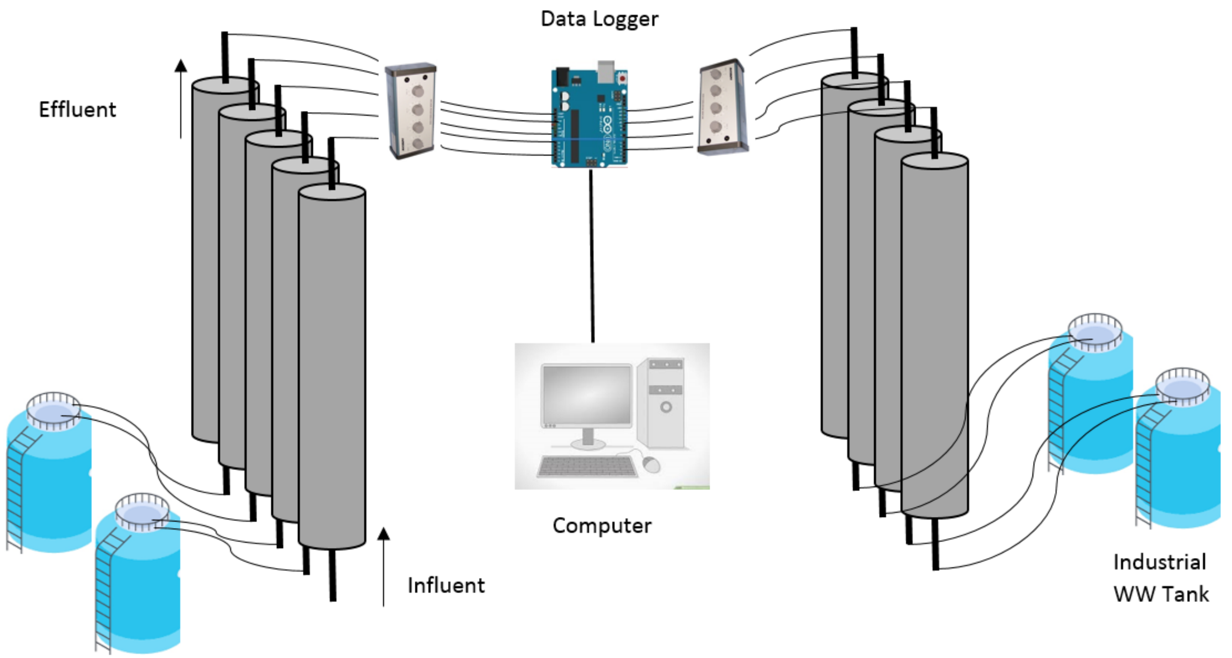
Materials and Methodology

1. Selection of industrial wastewater streams.
   - These are the most common industries in Kuwait: refineries, dairy factories, detergents factories, and soft drinks factories.

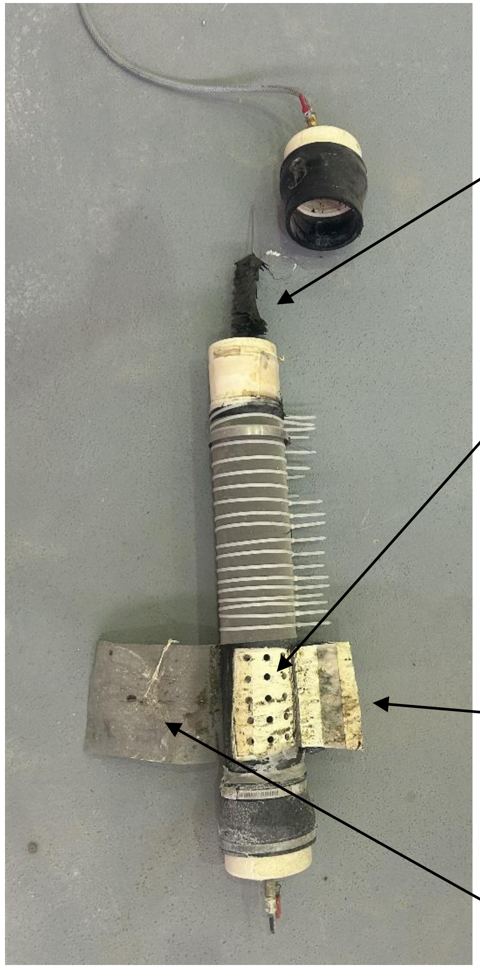
2. Nine tubular MFCs were designed, fabricated and installed at the Kuwait Institute for Scientific Research (KISR) workshop.

Cont., Materials and Methodology

(PVC) pipes - 75 cm (H), 10.5 cm (D) and an overall volume of 6.5 L



The MFCS were inoculated with AS from a domestic WWTP



Carbon brush Anode connected to Titanium wires

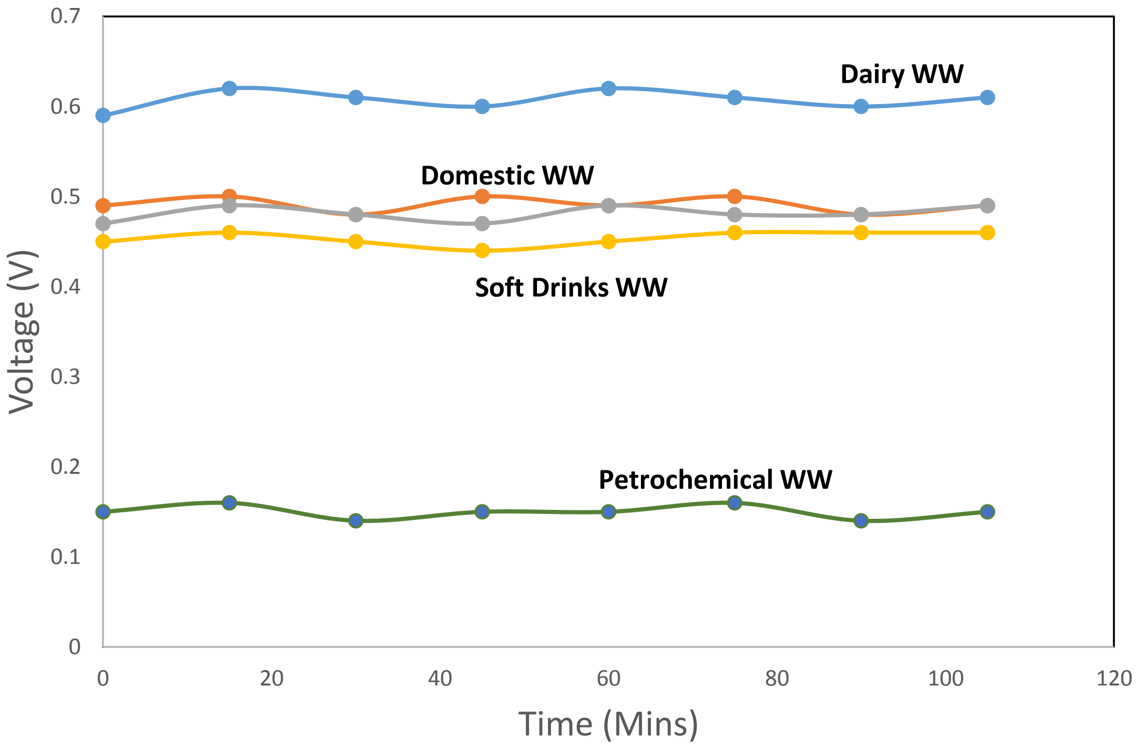
The PVC pipes had (1 cm) holes with an equal spacing of 2 cm.

The PVC pipe was wrapped with a cation exchange membrane

S.S. wire mesh wrapped around the pipe act as an electron collector

Results

- All the MFCs were continuously operated for >120 days, and the generated electricity varied depending on the industry.
- All MFCs generated electricity with **maximum open voltage** of:
  1. Dairy wastewater: **0.62 V.**
  2. Domestic wastewater: **0.5 V.**
  3. Detergent wastewater: **0.49 V.**
  4. Soft drinks wastewater: **0.46 V.**
  5. Petrochemical wastewater: **0.16 V.**



Results

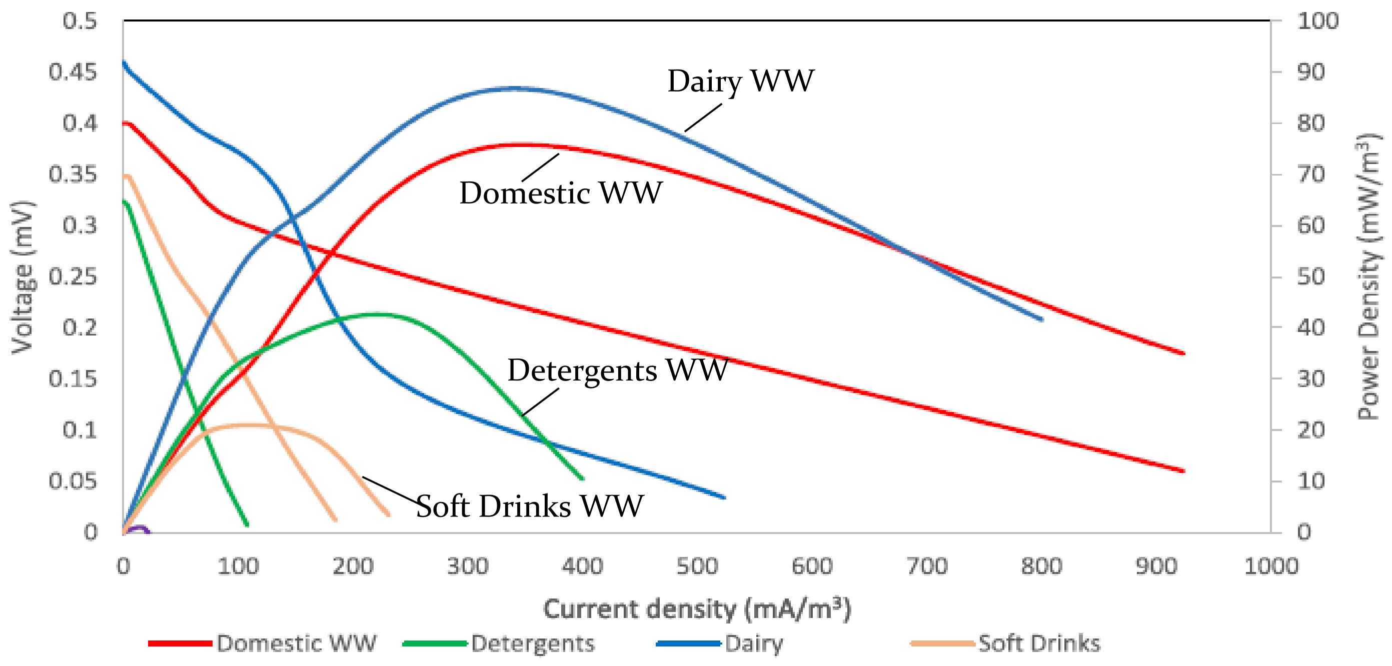
- In term of Coulombic efficiency (CE), all MFCs had low CE between 0 to 2.9 %.

Table 1. Summary of Average CE from Previous Studies.

Reference	Average CE %	Volume	Substrate
This Study	0.61 ± 0.24	6.5 L	Real WW
This Study	0.44 ± 0.18	6.5 L	Detergents
This Study	0.30 ± 0.10	6.5 L	Dairy
This Study	0.02 ± 0.00	6.5 L	Petrochemical
This Study	0.75 ± 0.19	6.5 L	Soft Drinks
Ghadge et al. [31]	0.23	45 L	Synthetic WW
Wu et al. [32]	1.00–3.00	12 L	Synthetic WW
Mohamed et al. [33]	0.60	0.1 L	Dairy
Antonopoulou et al. [34]	1.90	0.3 L	Synthetic

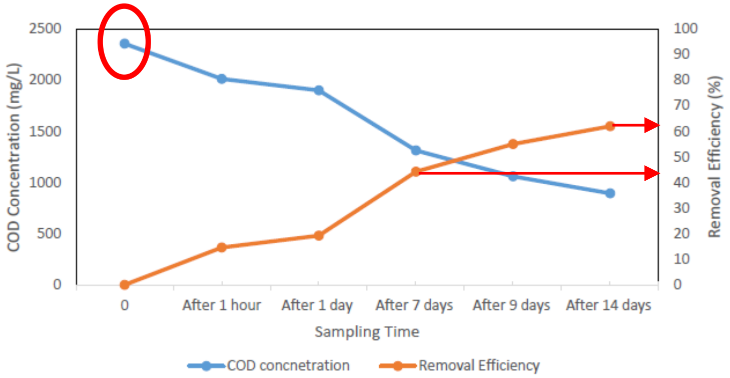
Results

- The MFCs generated the **highest power density** of:
  1. Dairy MFC 86 mW/m³.
  2. Control MFC 74 mW/m³.
  3. Detergent MFCs 41 mW/m³.
  4. Soft drink MFCs 20 mW/m³.
  5. Petrochemical MFCs 1 mW/m³.

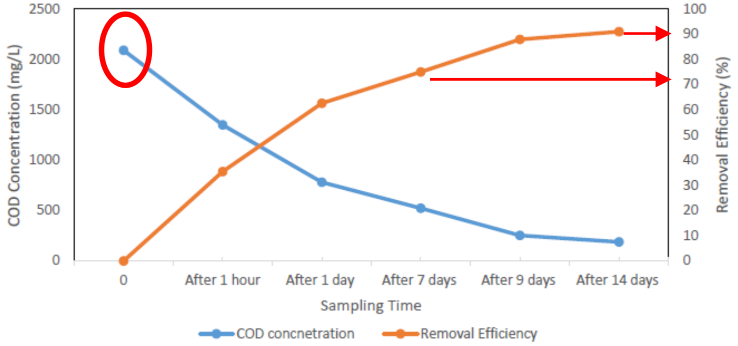


Results (Wastewater Treatment)

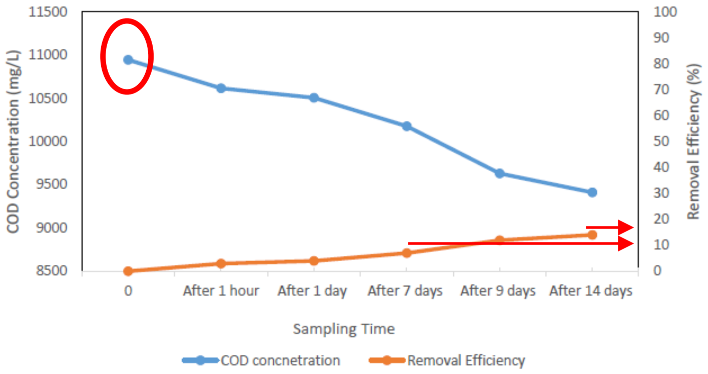
- The MFCs achieved high COD removal, except for the petrochemical MFCs.



Detergents WW

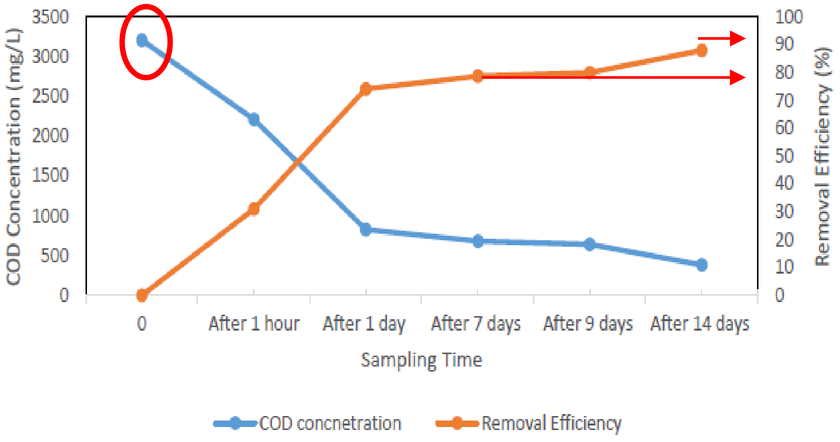


Dairy WW

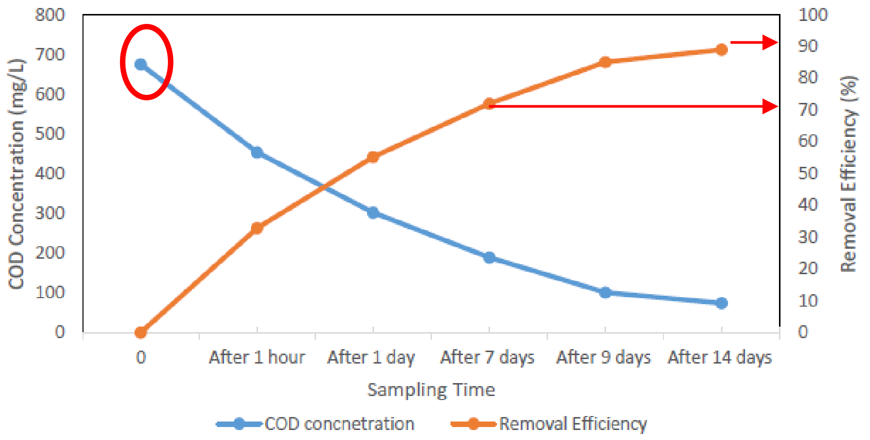


Petrochemical WW

Results (Wastewater Treatment)



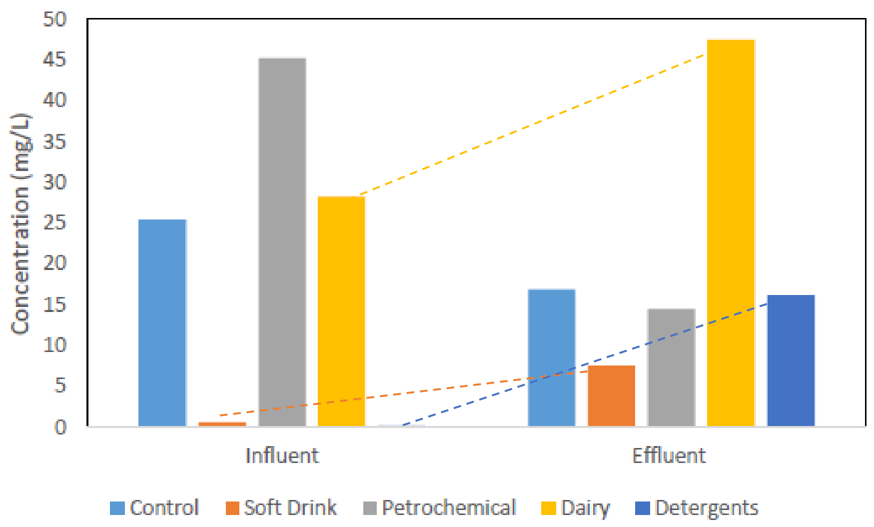
Soft Drinks WW



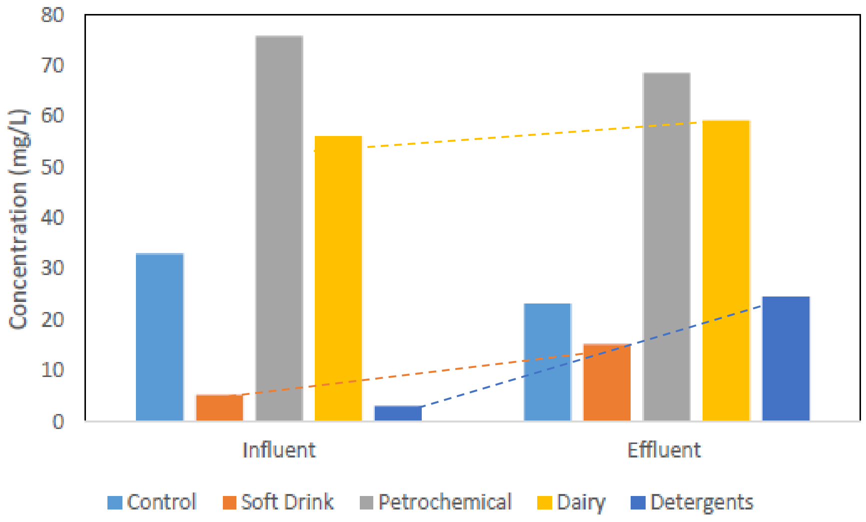
Domestic WW

Results (Wastewater Treatment)

- The concentration of N increased in most of the MFCs, except for the domestic and petrochemical MFCs.



NH_3



TN

Results (Internal Resistances)

- The internal resistances in the fabricated MFCs were high, and there is no correlation between wastewater type and internal resistance.
- Pearson coefficient analysis shows a negative correlation between the generated electricity and the internal resistance.

Table 2. Correlations between Voltage and Internal Resistance (Ω) in the MFC

	Internal resistance (Ω)
Voltage (Control)	-0.563
Voltage (Detergents MFCs)	-0.976*
Voltage (Dairy MFCs)	-0.657
Voltage (Soft Drinks MFCs)	-0.737*

* Correlation is significant at the 0.05 level (2-tailed)

Conclusion and Recommendations

- The characteristics of different industrial wastewaters have great influence the applicability of MFC technology.
- The dairy industry achieved the highest potential in terms of electrical energy generation and organics removal. Thus, MFCs have the potential for full-scale application.
- In petrochemical MFC, the inhibitive chemicals, hydrophobicity of chemicals leading to catalyst deactivation, and generally un-favourable microbial growth conditions.

Recommendations

- Improve the performance of MFC by using a more efficient and self-generating catalyst in the cathode electrode instead of carbon.
- Enhance the design of the used MFC by connecting more than one MFC in series and storing the generated electricity in storage battery.
- Integrate MFCs with other technologies to provide an efficient system for concurrent electricity generation and wastewater treatment.

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