Integrated hydroponic bioelectrochemical wastewater treatment process for sustainable agriculture

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Introduction and Motivation

Background

- Untreated wastewater effluents can raise nutrient and biomass concentrations in water bodies, causing serious harm to aquatic environments.
- However, conventional municipal wastewater treatment is energy-intensive (2% of total energy consumed in the US).
- Municipal wastewater contains up to 10x the energy needed for its own treatment.
- Hydroponics, a soil-less method of crop cultivation, can aid in and benefit from wastewater treatment.
- *This study aims to harness the untapped chemical energy in wastewater using microbial electrochemical cells (MEC) while boosting hydroponic crop growth.*

Typical Wastewater Pollutants:

N: NH_3/NH_4^+, NO_3^-, NO_2^-, Organic

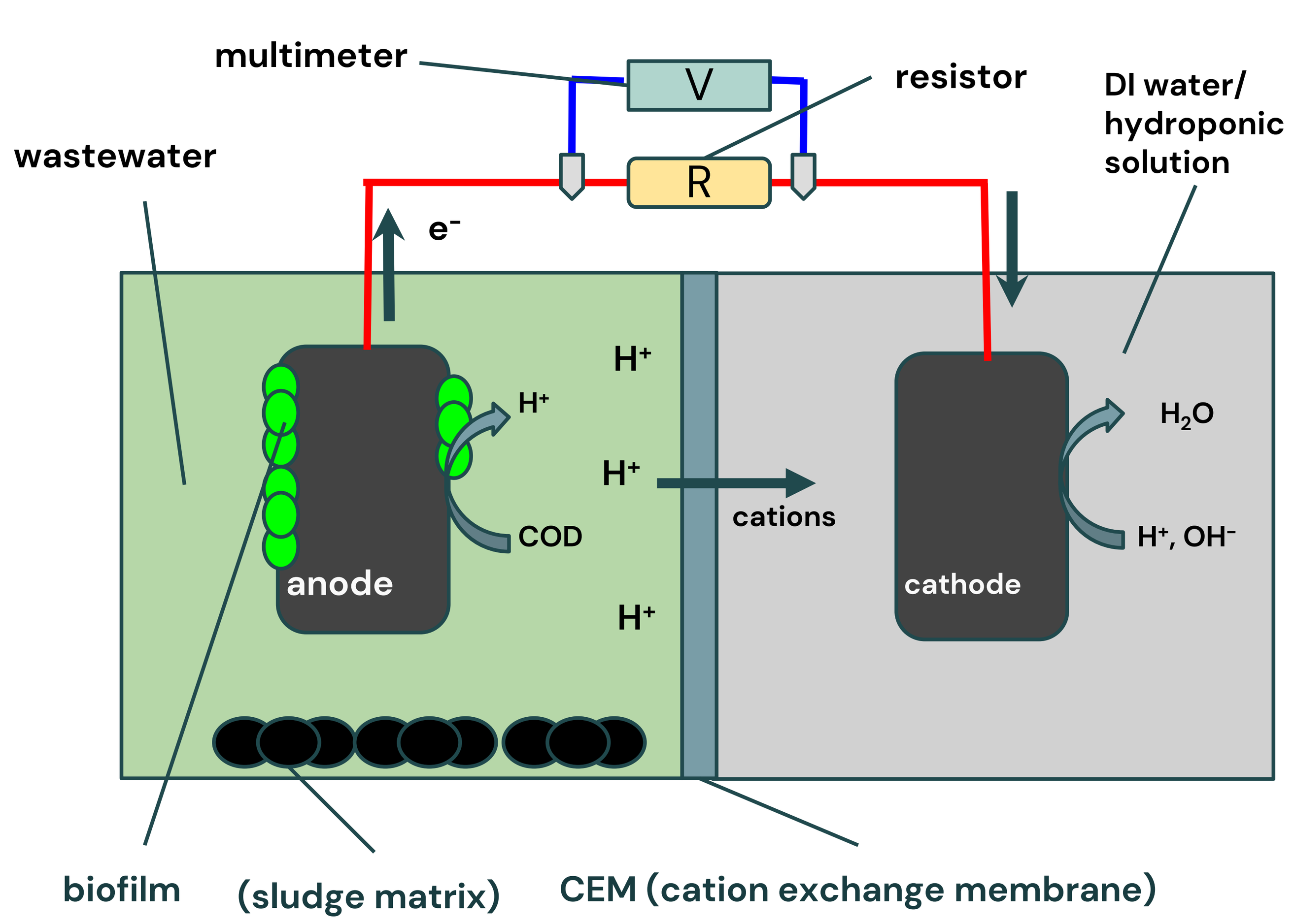
P: PO_4^{3-}, $(PO_3)_n$, Organic

Oxygen-demanding chemicals

Suspended solids

Heavy metals

Microbial Electrochemical Cell Mechanism



- **Anode:** electroactive bacteria treat pollutants in wastewater (oxidation)
- **Membrane:** facilitates exchange of ions
- **Wires + resistor:** conducts electrons (electrical current)
- **Cathode:** completes the circuit (reduction)

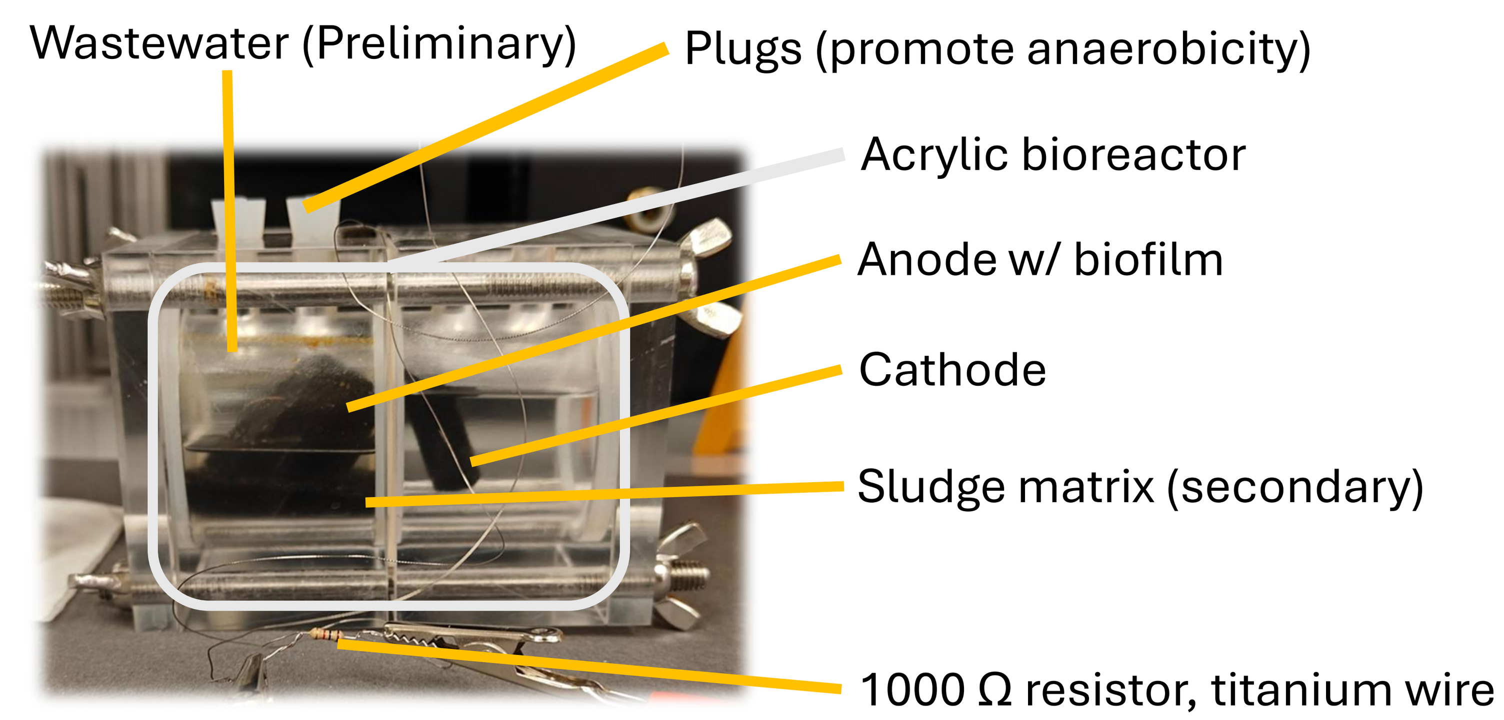
Anion Exchange Membrane (AEM) Transports negatively charged ions

Cation Exchange Membrane (CEM) Transports positively charged ions

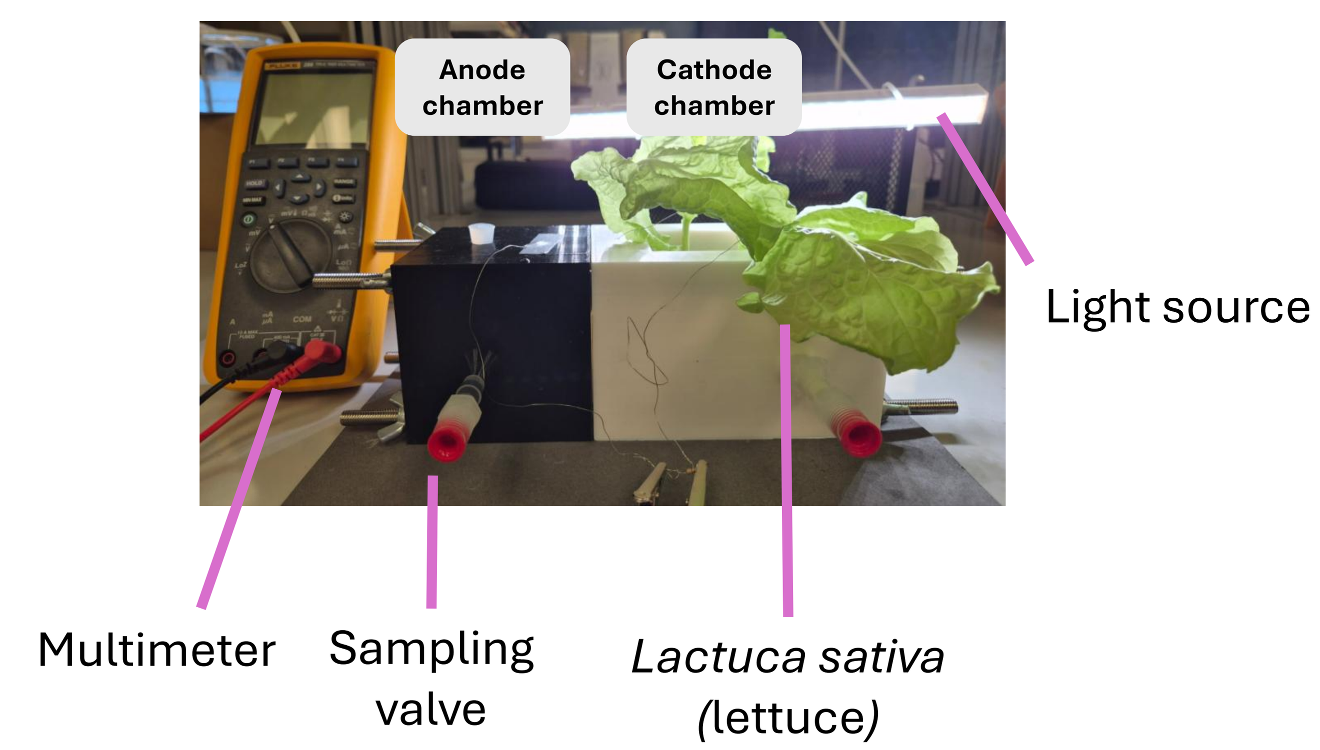
Proton Exchange Membrane (PEM) Transports only H^+ ions

Methods

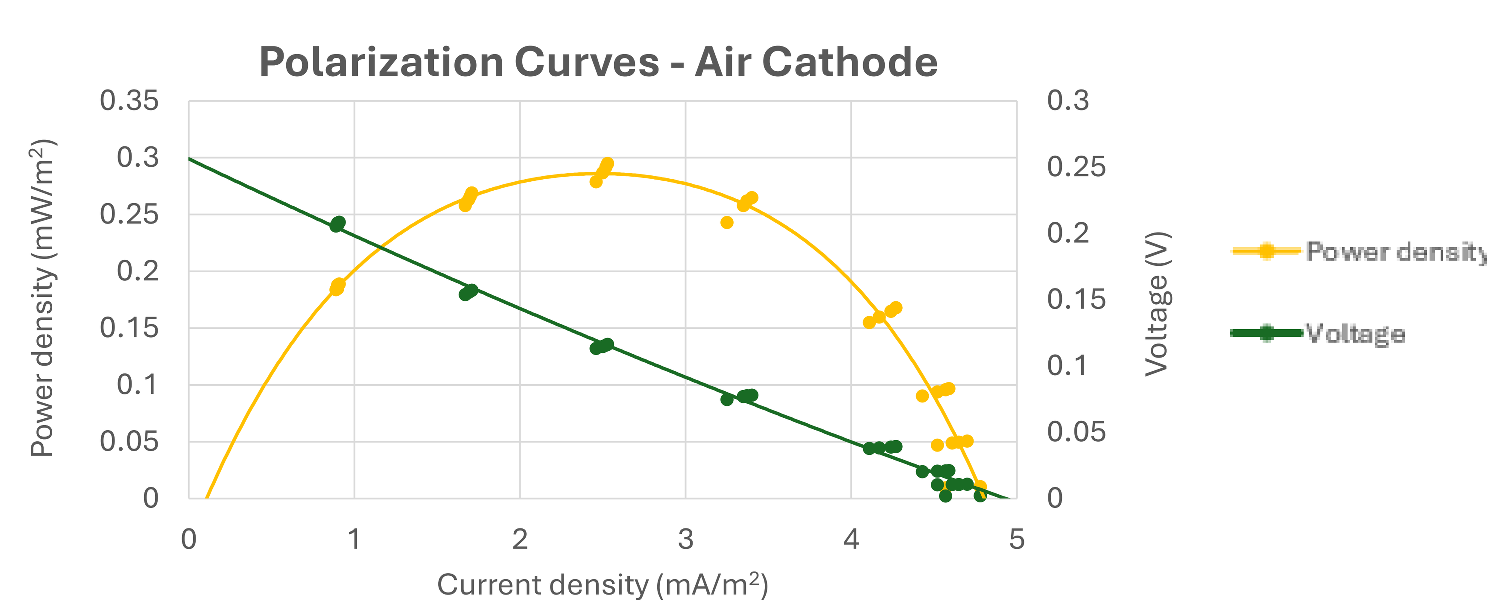
Air cathode configuration

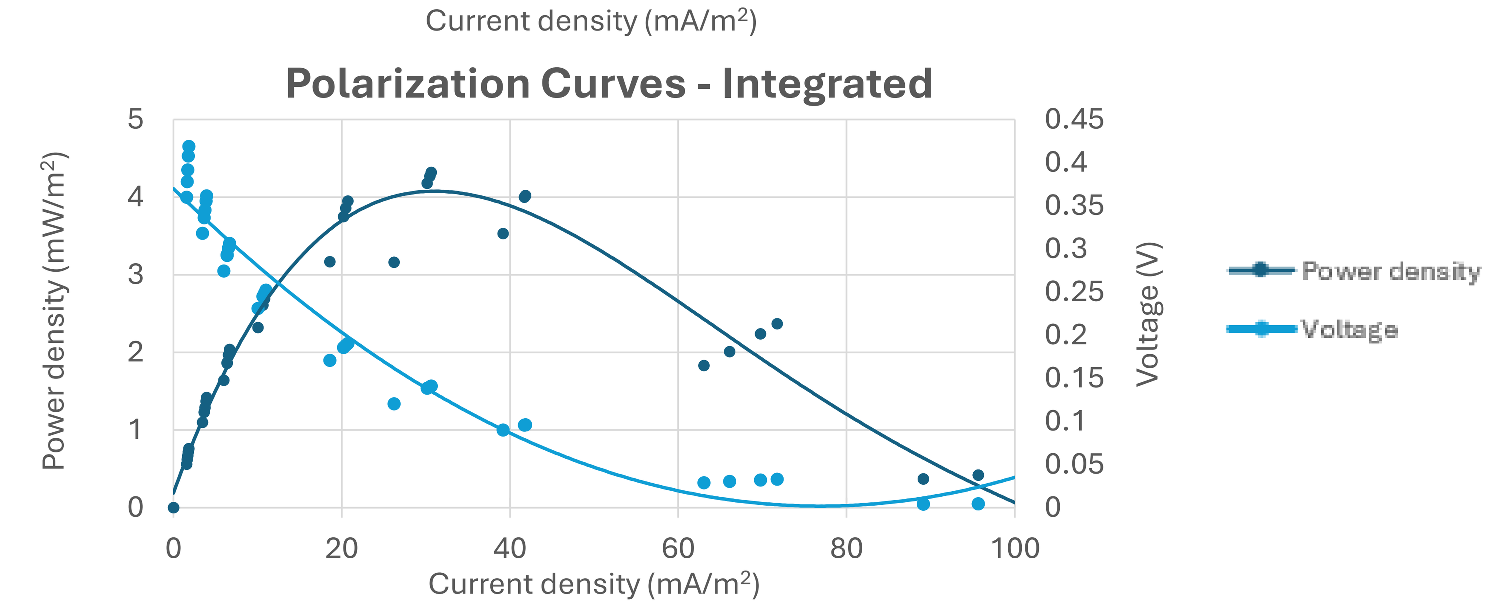


Integrated configuration



Results





System Performance

COD Removal Efficiency	● Air cathode: 61% ● Integrated: 57%
Total N Removal Efficiency	● Air cathode: 54% ● Integrated: 47%
PO_4^{3-} Removal Efficiency	● Air cathode: -15% ● Integrated: 13%
Coulombic Efficiency (CE)	● Air cathode: 3% ● Integrated: 12%
Peak Voltage	● Air cathode: 0.10-0.15 V ● Integrated: 0.16 V
Plant Growth (% change, wet wt.)	● Integrated: 25%

Discussion

- **COD and total nitrogen removal rates**
  - Integrated system lower, possibly due to reduced concentration gradient and subsequently, inhibited proton exchange
  - Higher initial COD concentration correlated with higher removal
- **PO_4^{3-} removal rate**
  - Air cathode: negative removal, likely due to leaching from sludge
  - Integrated: positive, likely due to osmosis from anode to cathode and improved assimilation rate by anodic biomass
- **Plant growth in integrated design:** significant decrease in cathodic total nitrogen and total phosphate suggests plant utilization of nutrients
- **Power production:** comparable potential despite using cheaper, environmentally-friendly materials

Future Work

- Bipolar membrane (BPM) experiments
- Kinetic analysis of COD removal
- Effect of combined hydroponic-MFC on lettuce growth and treatment times, long-term

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References

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