Evaluation of bioelectrochemical systems for wastewater treatment with energy recovery

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Wastewater Treatment

Some people see:

Problem that must be solved to avoid: Nutrient removal

Harmful algal bloom and fish kills due to nutrient overload and eutrophication

Wastewater Treatment

Other people see:

Opportunity, WHILE solving the problem

Clean water and healthy fisheries

Energy Recovery Potential in WWTP

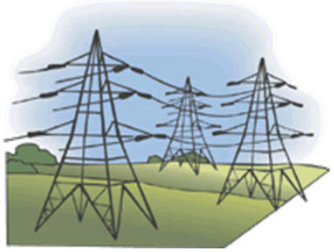
Wastewater treatment

378 l/person·day
200 mg COD/L

Energy in wastewater = 3.3-7.2 TWh
Saved energy (aeration) = 7.3 GWh

Treated wastewater
Biosolids

= 1-2% of total US electricity consumption
= 3-6 mio US households

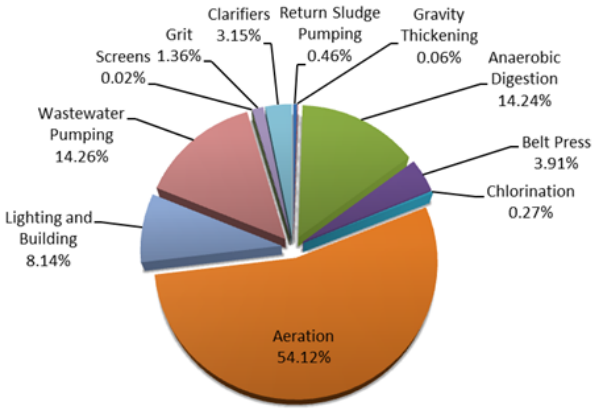


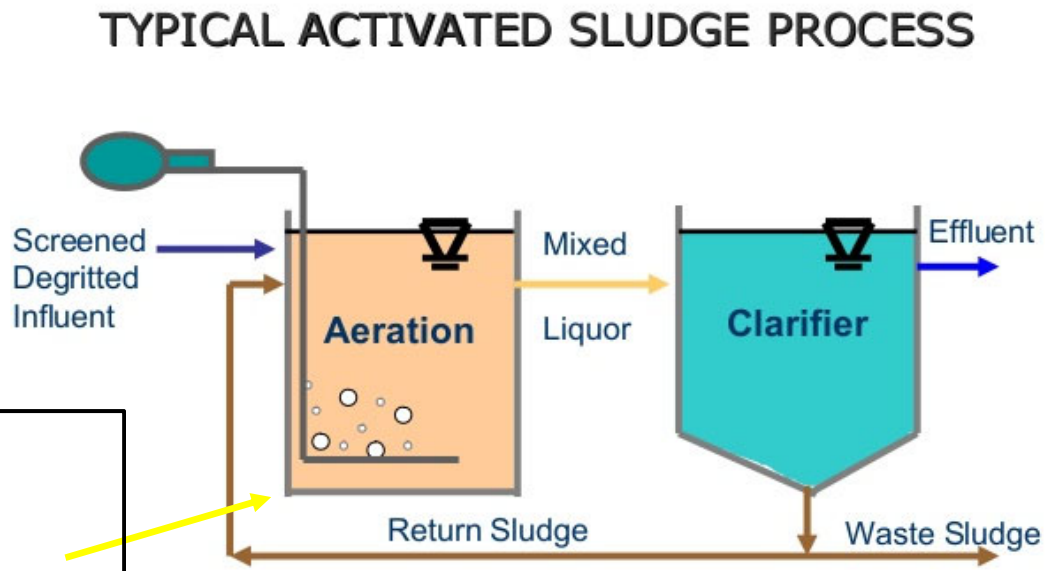
Leininger et al 2019

Blue Plains WWTP– Biggest Pepco bill in Washington, DC!

Wastewater:
378 liters/person*day
200 mg COD/L
~7 kJ/L

Input:
21 billion kWh /yr
@DC Water, $10 million/yr





$organics + O_2 \rightarrow CO_2 + H_2O$ (microbes)

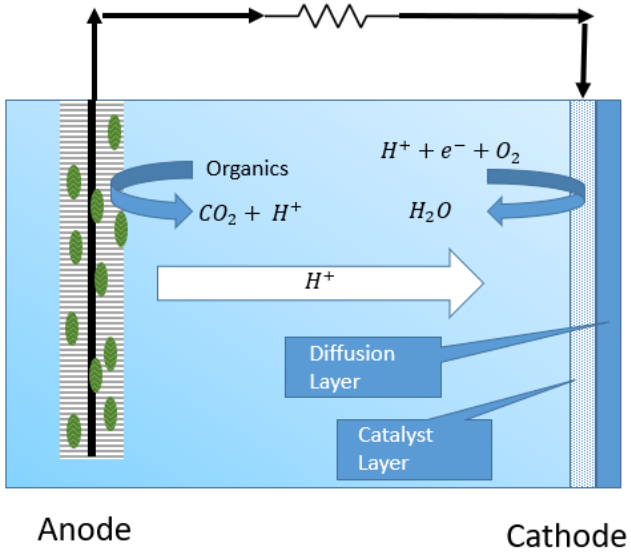
e^-donor | e^-acceptor

Waste heat

Heidrich, 2011. Determination of the internal chemical energy of wastewater
Energy Resources Center, 2016 (http://www.erc.uic.edu/)

Microbial Fuel Cell Overview

- Degrades organic matter (COD) without need for aeration
- Anaerobic system
- Creates useful electric energy (or recycling of electrons)
- Spatially separated oxidation and reduction



Microbial Fuel Cell (MFC)

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District of Columbia Water and Sewer Authority

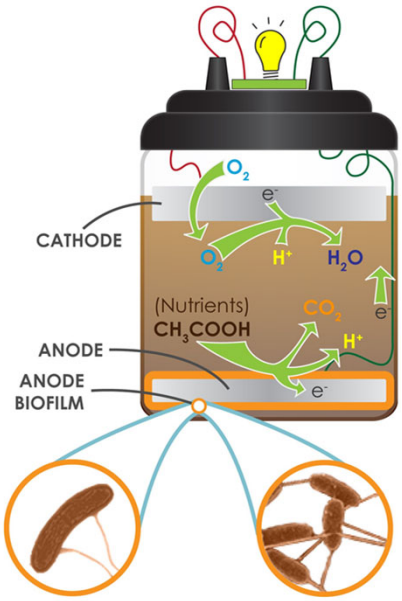
Focus of Research:

- Transformation of complex COD in wastewater using MFC
- Pilot scale MFC

DC Water – Pilot Scale

Objectives:

- Evaluate locations with high COD concentrations
- Identify bacterial populations – are electrogenic organisms present?
- Anode design – this is not glucose or acetate(!)
- Scale up



Goals:

<u>High energy recovery</u>

- As electricity to the grid
- As electrons to reduce need for aeration
- Secondary: as H_2 and CH_4
- Later: Removal of Persistent Organic Pollutants)

⇒**Return on investment time**

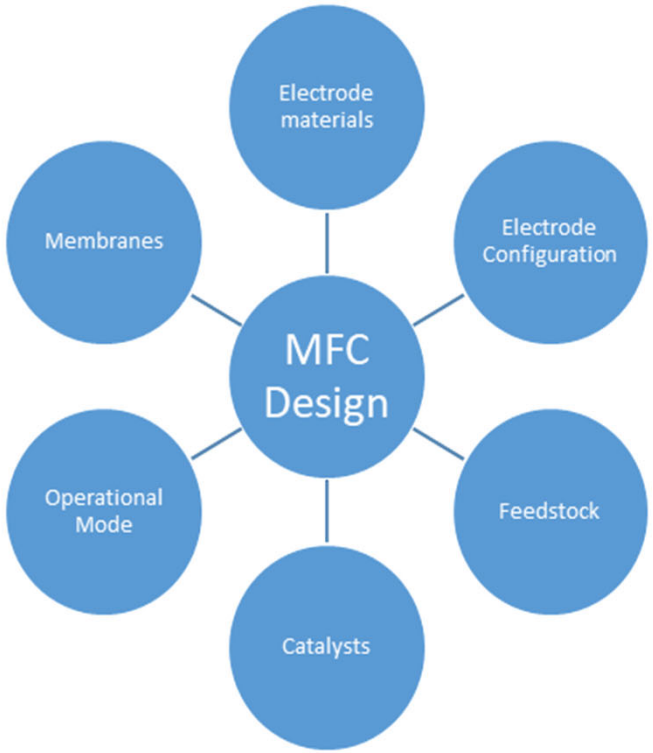
Pilot-Scale Design

Implementation of upscaled microbial fuel cells for optimized net energy benefit in wastewater treatment systems

Aaron Leininger et al (2019),
ASCE Journal of Environmental Engineering

Recent advances –

- Affordable cathode materials
- Biocathodes/ alternate e-acceptors
- Use of high-strength domestic WW blend



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Pilot Design – Site Selection

- Criteria:
  - Access to feedstock
  - Disruption to operations
  - Risk of system failure
  - Environmental Control
  - Building/Fire Code

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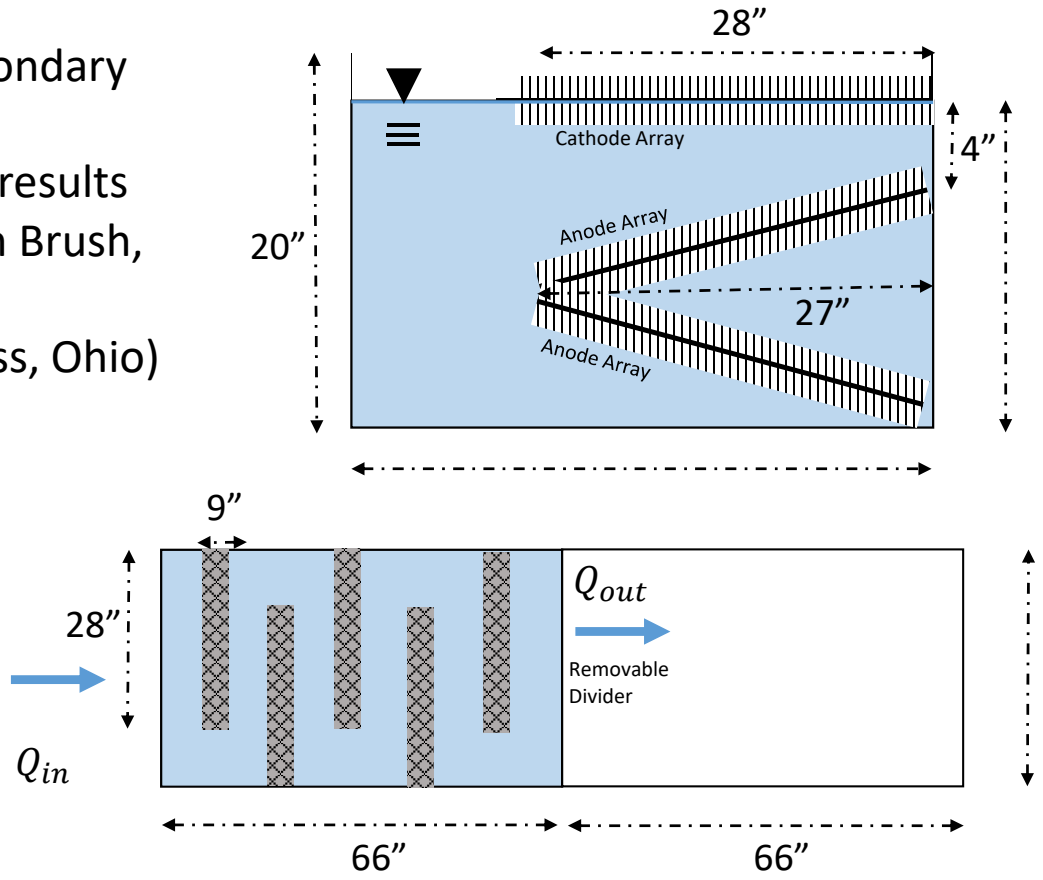
Pilot-Scale Design

- Based on 10% Dimensional Scale of East Secondary Reactor
- Feedstock blend determined by bench scale results
- Carbon Fiber brush anode/cathodes (Gordon Brush, California)
- MFC Volume – 216 gallons (Formed Fiberglass, Ohio)
- HRT – 1 day
- Flow rate – 9 gallons/hour



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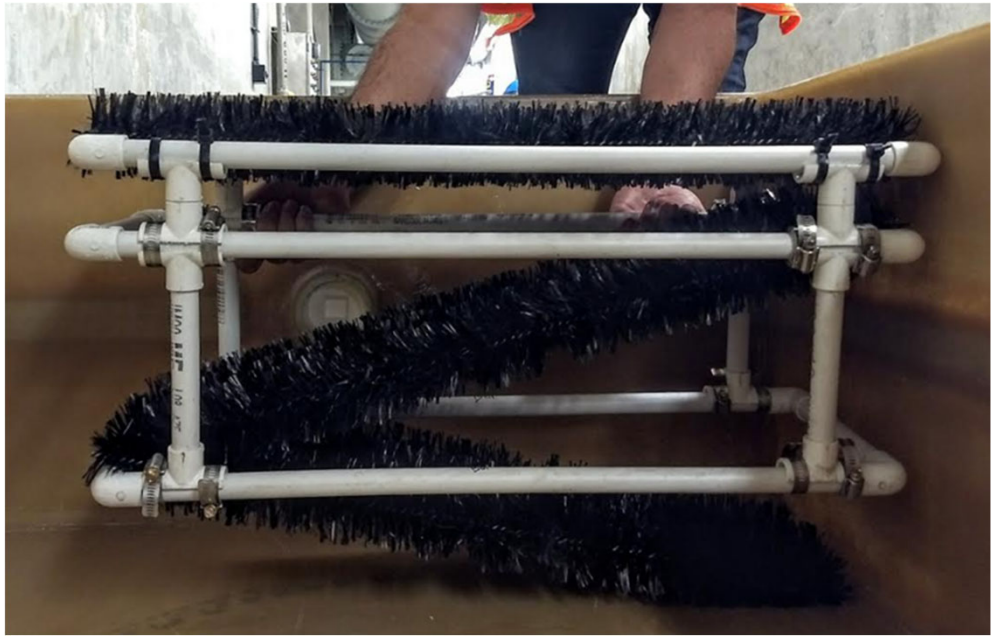
Module Construction

- Insertable modules
- Epoxy sealed electrical connections
- Anode modules designed as baffle structure to promote plug flow
- No modification or catalyst applied to cathode brushes
- Ag/AgCl reference electrode inserted along with Module 5



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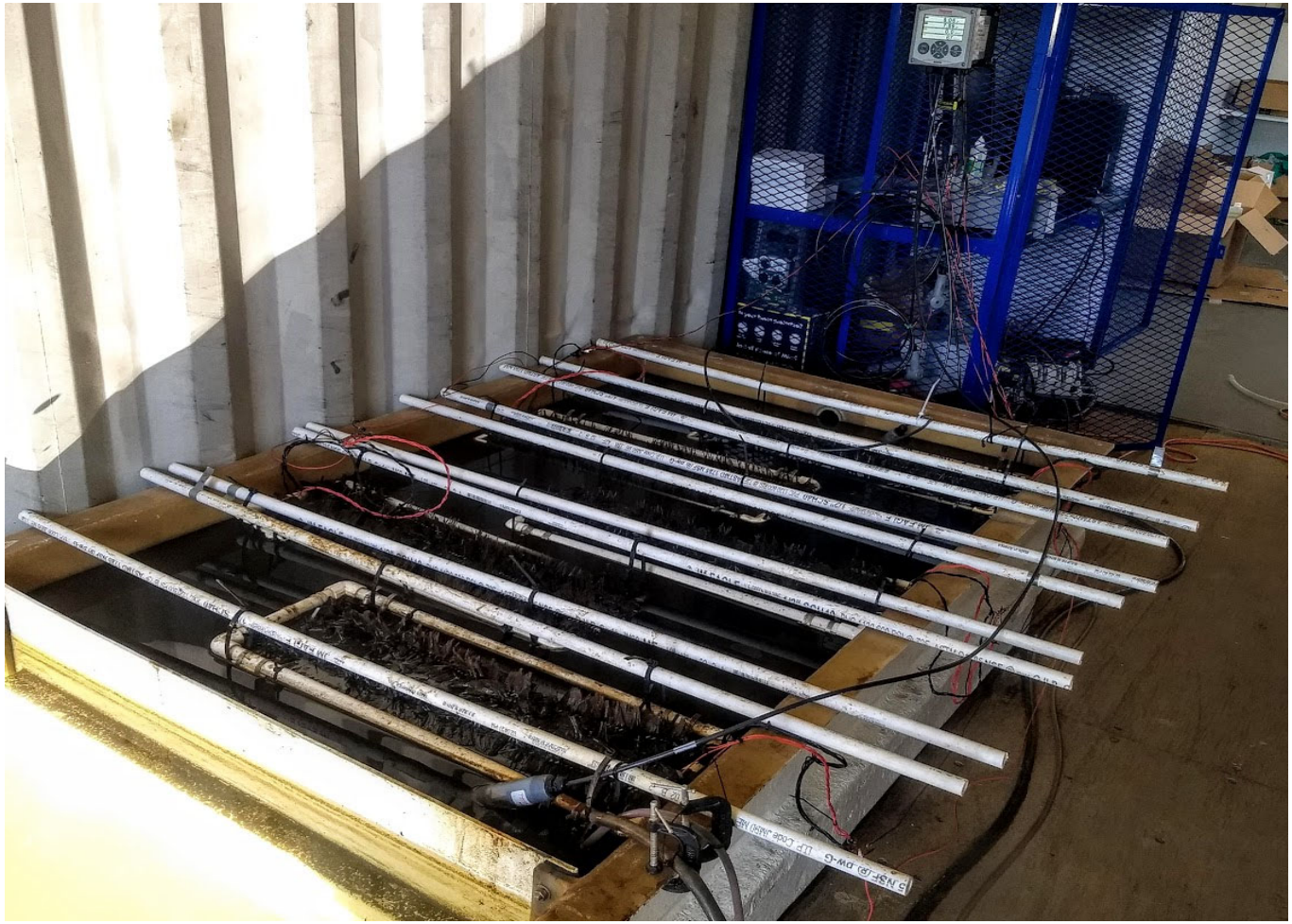

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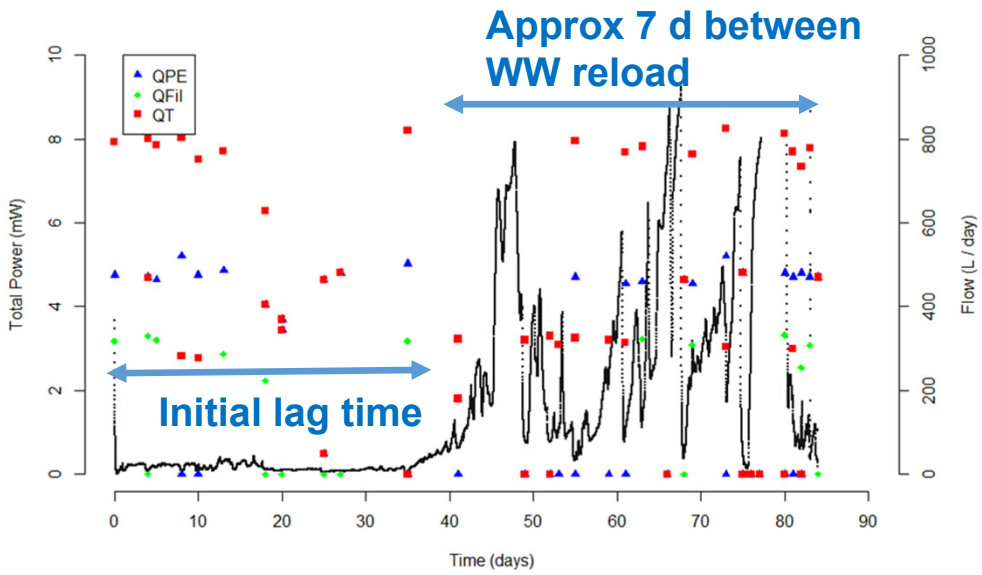
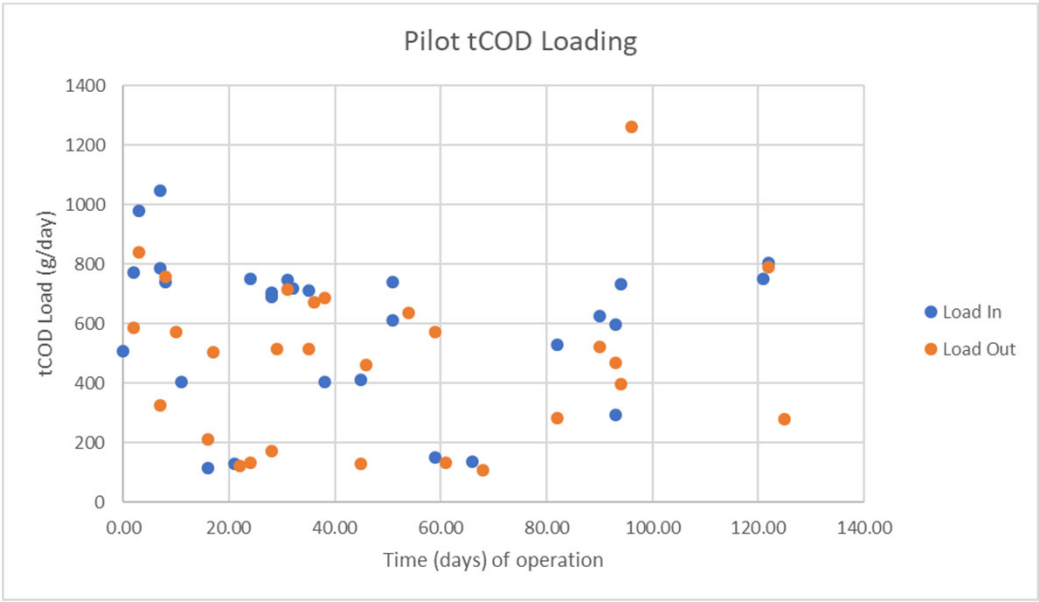
Results: Power output & Org. matter

Power output



Organic matter removal



Conclusions:

1. It works!
2. Total power output varies with org. matter availability in WW
3. Organic matter removal varies: 30-75% removal

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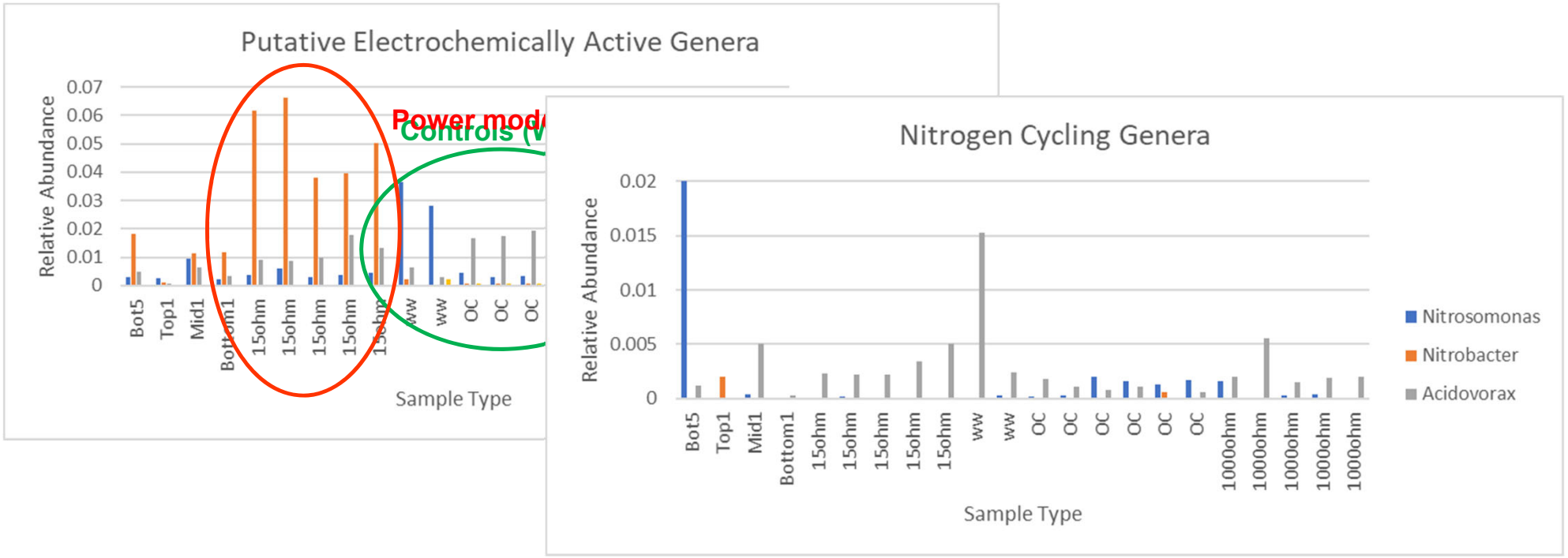
Bacteria in the anode biofilm



Conclusions:

1. Native bacteria can do the job! No seeding needed.
2. The biofilm populations change with increased resistance.
3. Nitrogen removal is also possible.

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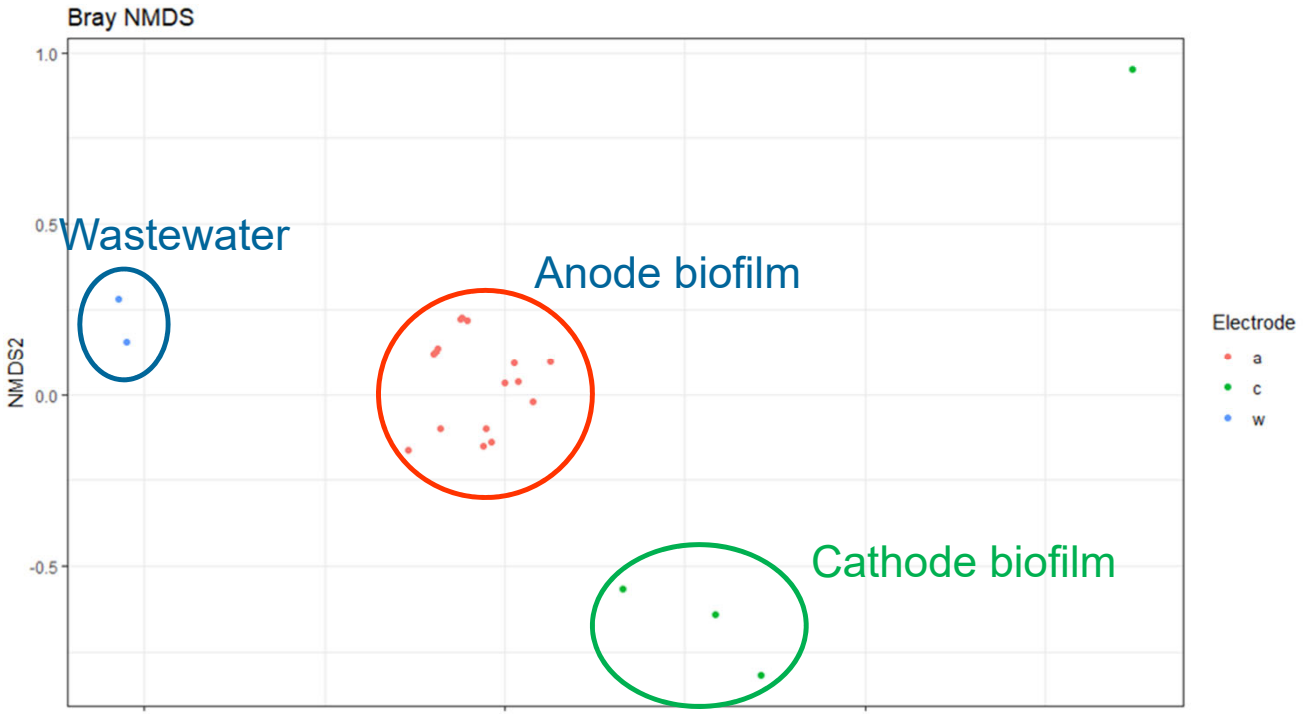
Diversity biofilms?



Relationships based on calculated diversity indices of bacterial populations in all samples (location in tank, time, location at anode brush)

Conclusions:

1. Inoculum, anode and cathode biofilms are different
2. Changes in diversity over time and location occur, but…
3. Distinct bacterial communities form in the MFC

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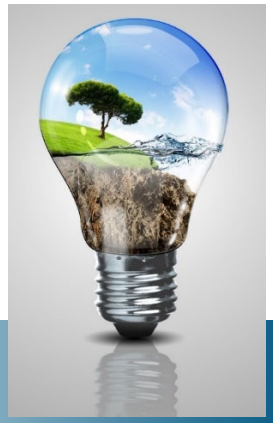
Summary

Pilot Scale Microbial Fuel Cell:

- Not only treatment of nutrients
- Also RESOURCE recovery: Water, energy, nutrients
- Study: Highest potential for energy recovery in mixed WW of primary effluent and filtrate

Opportunities:

- Increased N removal efficiency (save on aeration)
- Removal of Persistent Organic Pollutants, pharmaceuticals
- Treatment of industrial wastewater with high organic matter content and/or specific contaminants



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Kjellerup Biofilm Laboratory

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dc water is life