Usage of Microbial Fuel Cell Technology in Landfills. Year II. Enhanced Organic Compound Decomposition and Nitrogen Removal

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Ammonium Source in Landfill Leachate

- Protein
- 0.5% of Dry Weight of Municipal Solid Waste

Landfill Leachate with High Ammonium Content

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- Organic Decomposition
- Nutrient Removal
- Energy Generation

Landfills at Isolated Locations

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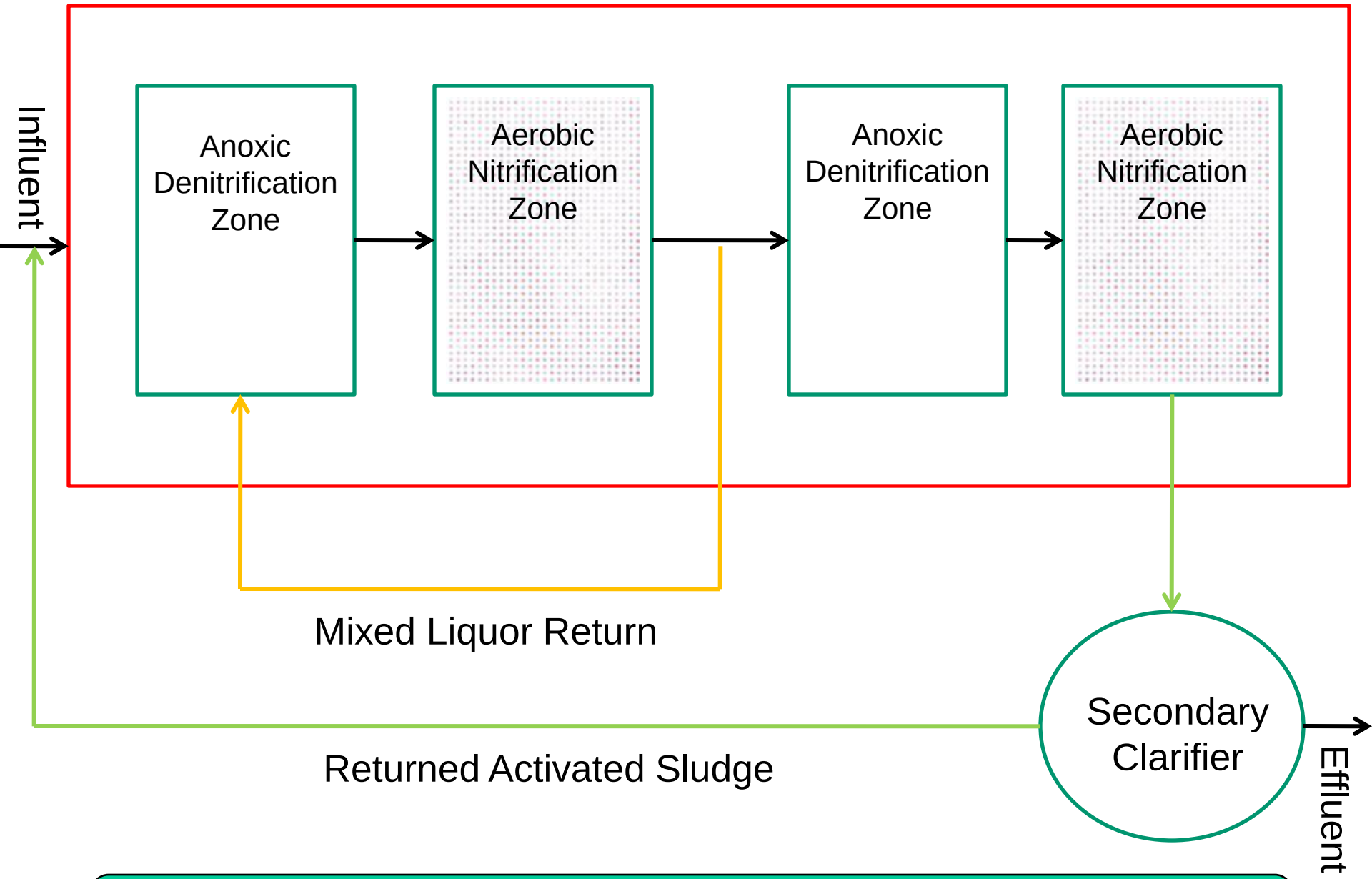
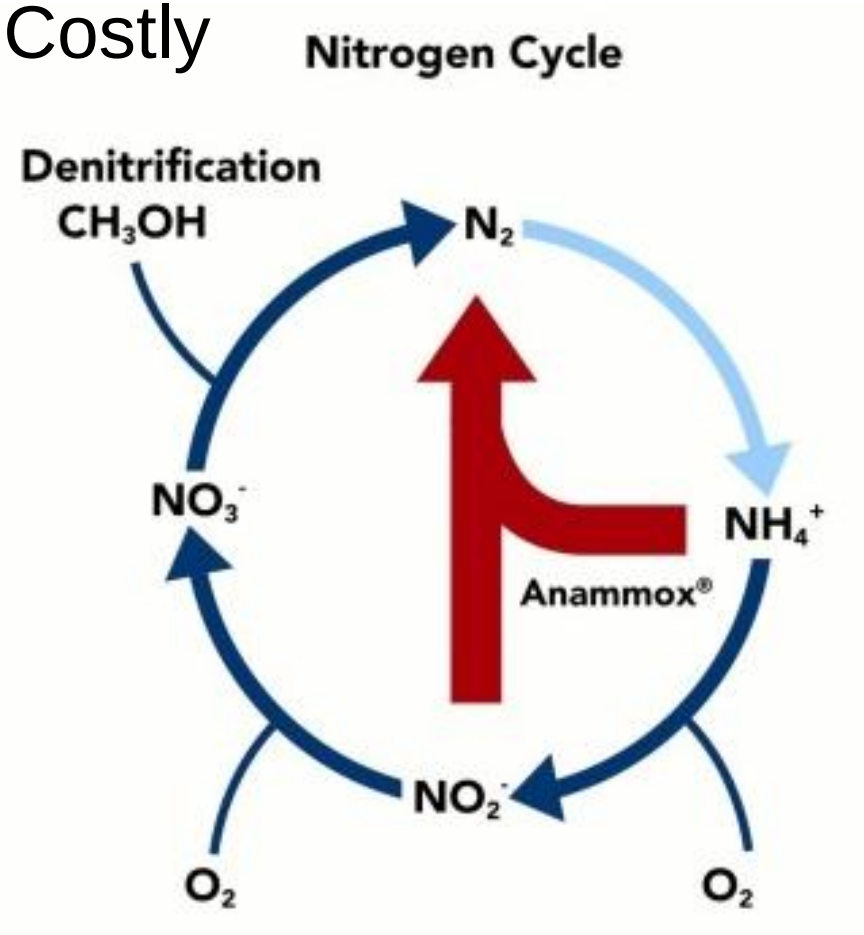


4-Stage Bardenpho Biological Process

- Efficient
- Costly



Anammox for Ammonium Removal

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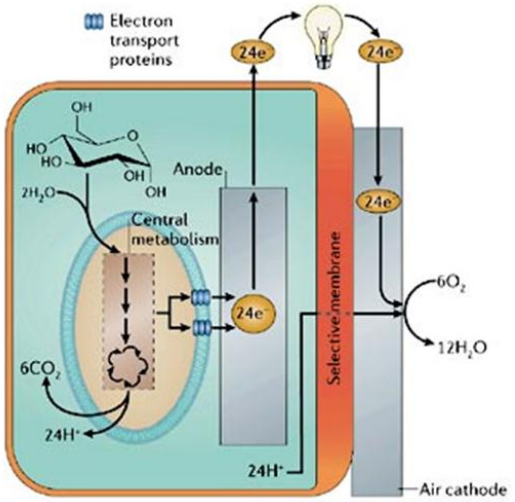
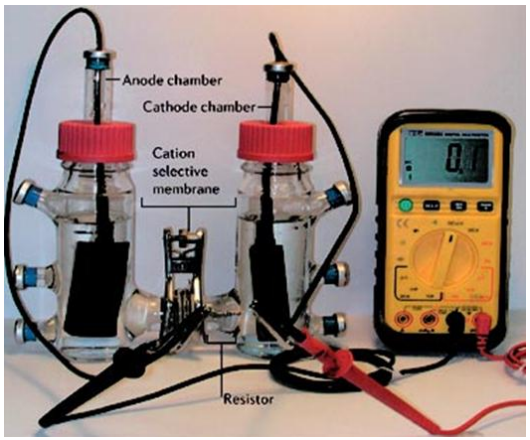
Electricity Generation





Electron Consumption Separated from Organic Carbon Oxidation

- Landfill Leachate organic Compound Decomposition

$$C_{12}H_{22}O_{11} + 13H_2O \rightarrow 12CO_2 + 48H^+ + 48e^-$$

- Electricity Generation

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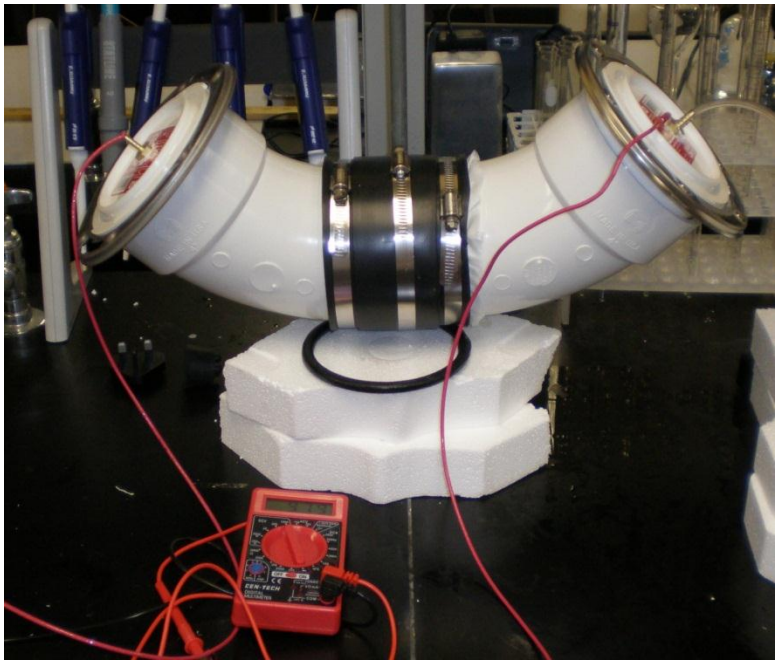
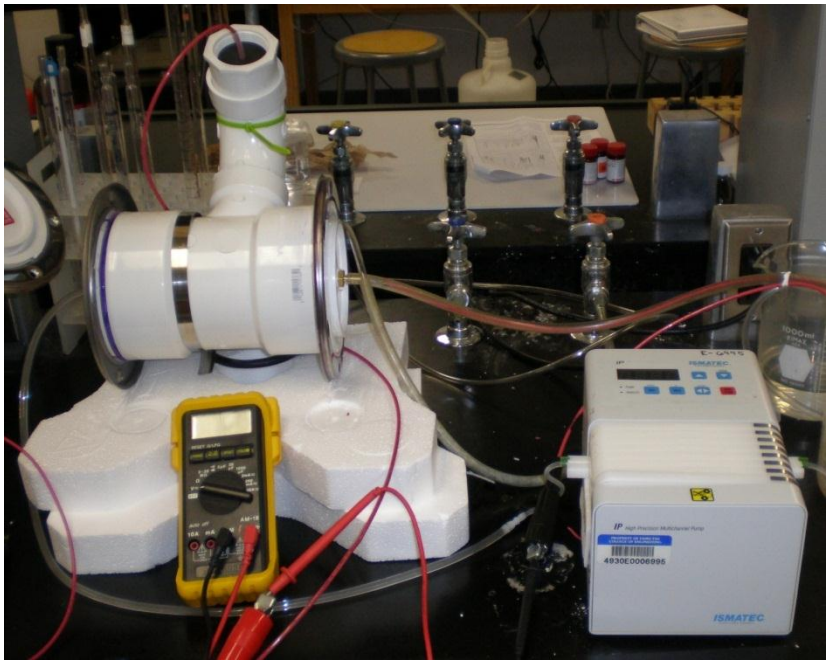
Prior Research — Microbial Fuel Cell





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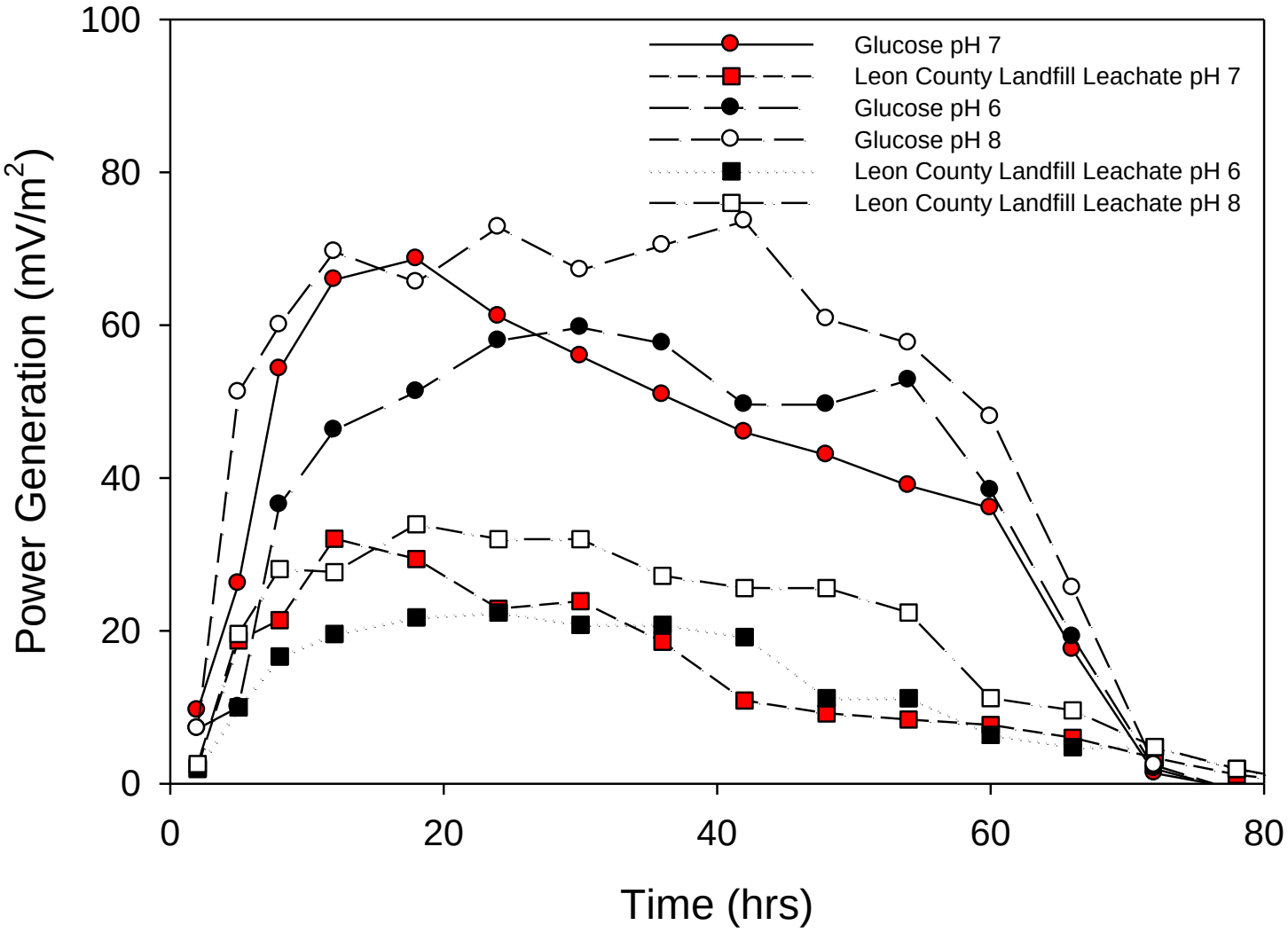
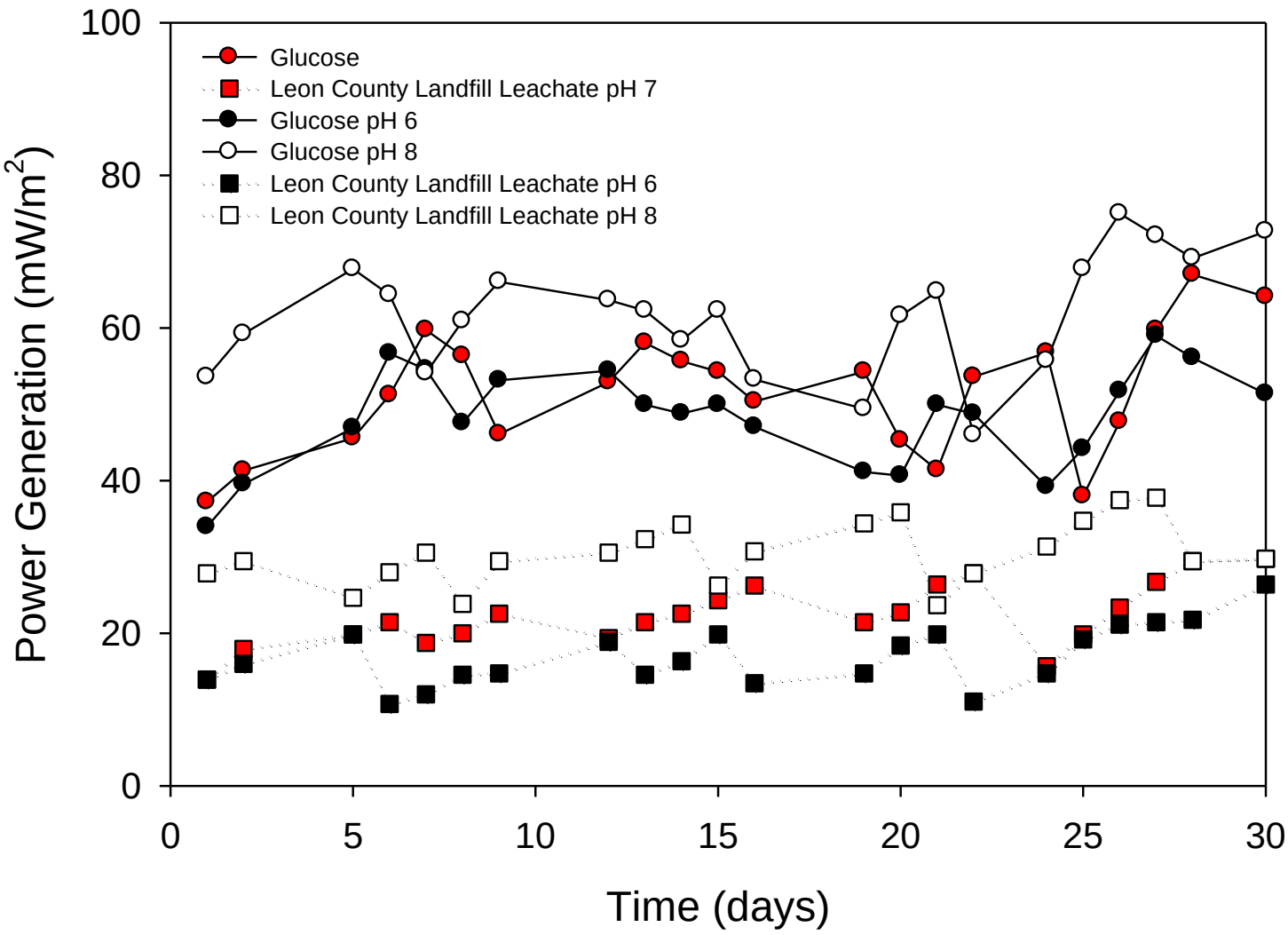
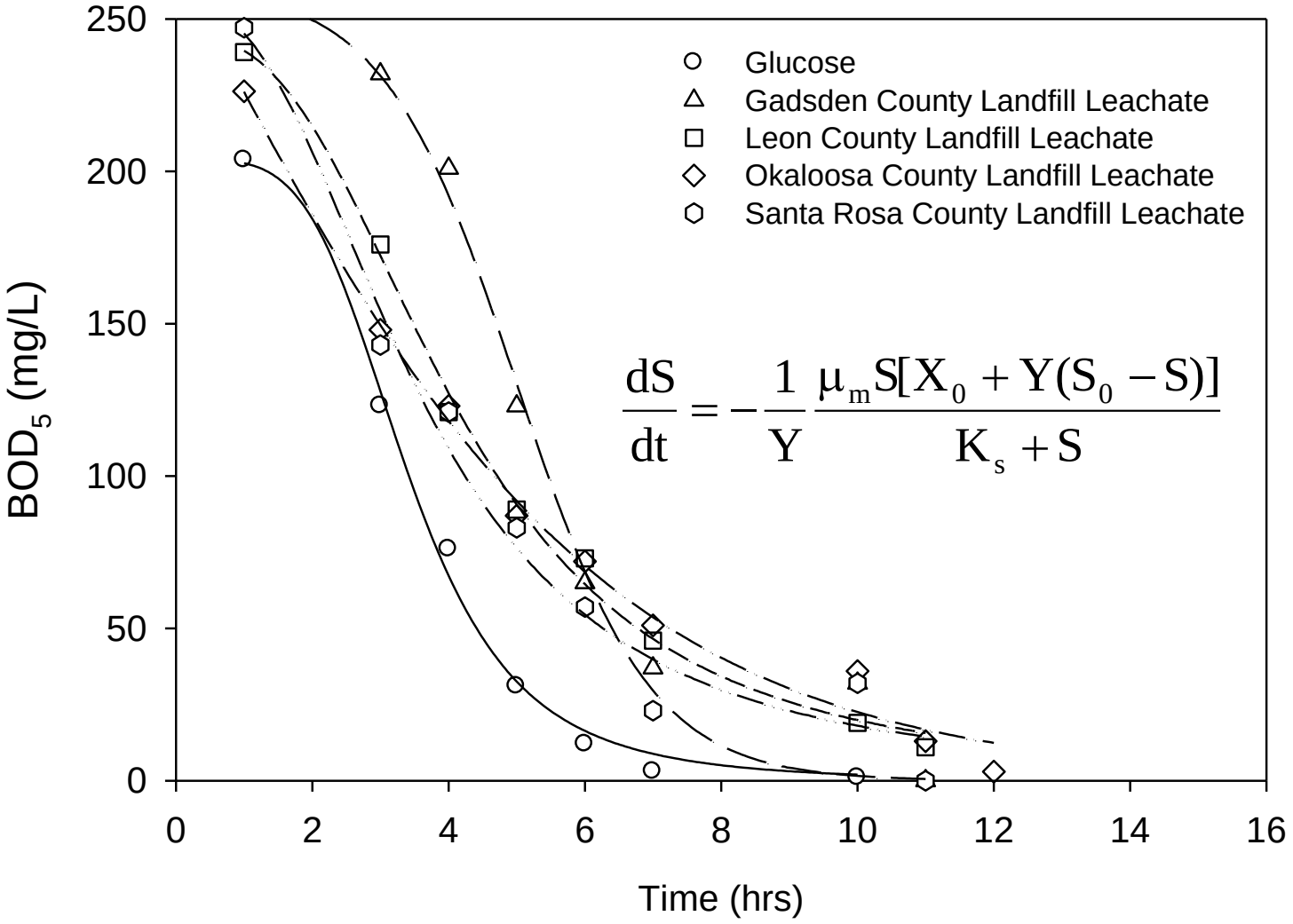
Power Generation — Batch MFC



Power Generation — Continuous MFC



Organic Decomposition



Organic Decomposition

	K_S (mg/L)	Y (g/g)	μ_{max} (day^{-1})
Glucose	154.3	0.678	0.0124
Gadsden County	271.6	0.323	0.0072
Leon County	172.1	0.412	0.0089
Okaloosa County	163.7	0.486	0.0105
Santa Rosa County	174.5	0.421	0.0093

Iron Release in NW Florida

Central Landfill
Walton County

Fairgrounds Branch below
Auto Shred Landfill

Visible Iron Release nearby Landfills

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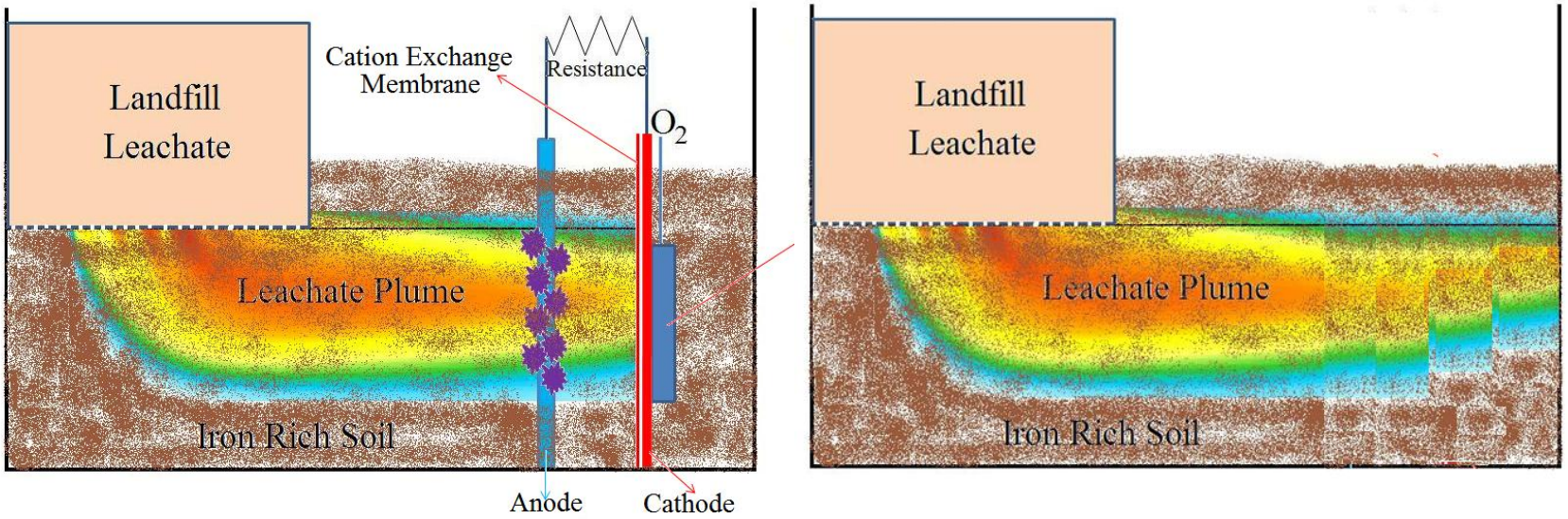
Iron Release Prevention Experiments

Parallel Control Experiments



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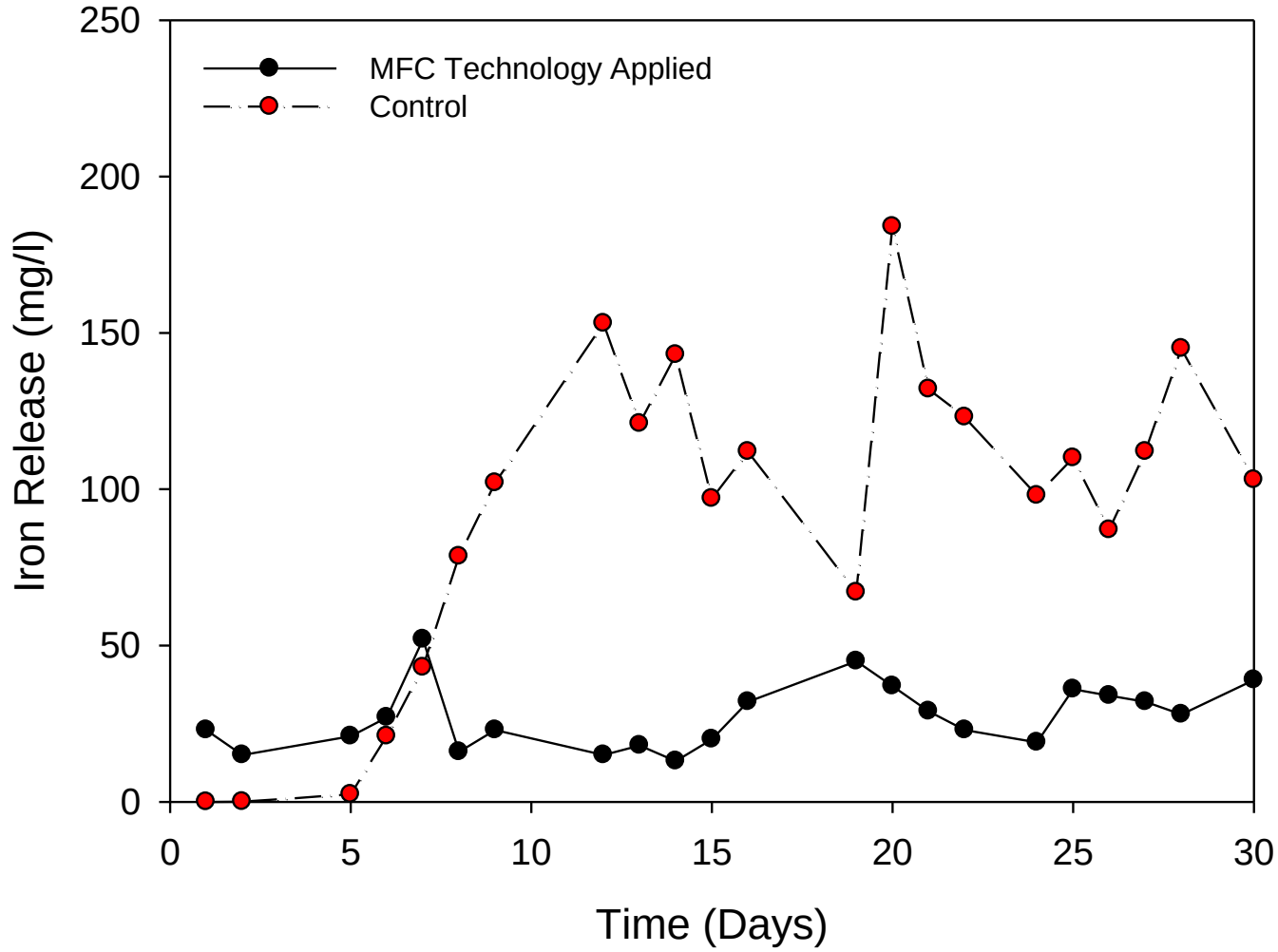
Iron Release Prevention Results



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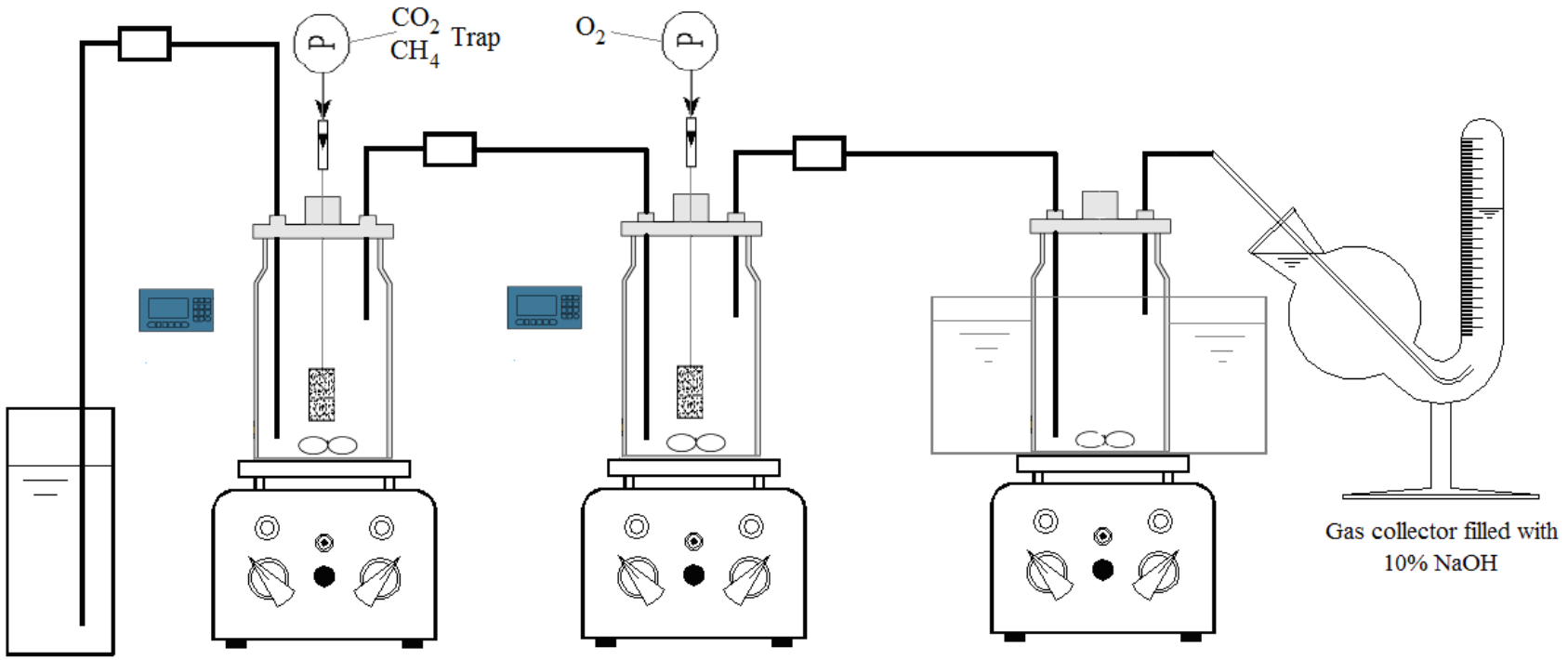
Prior Research – Anammox



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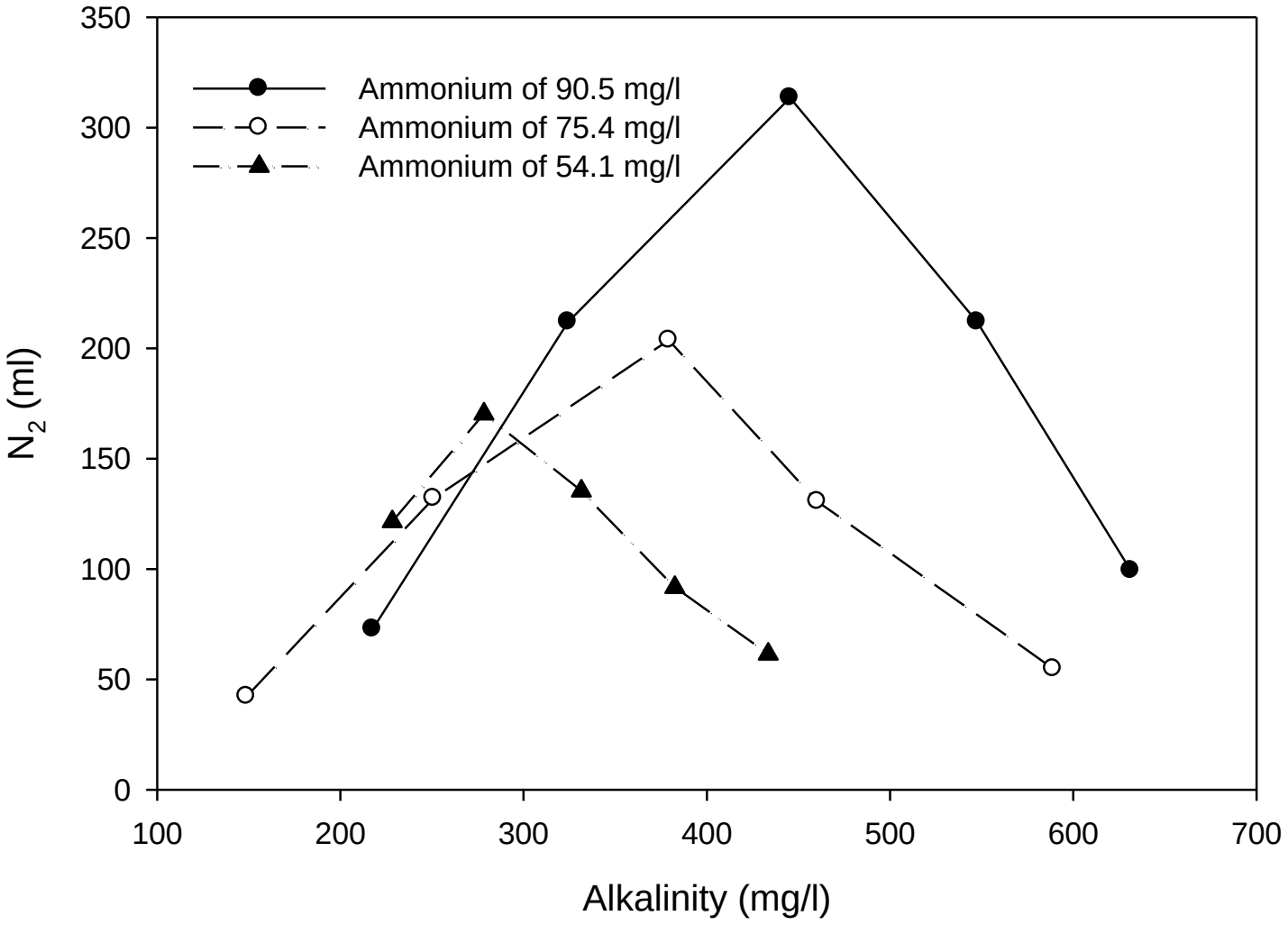
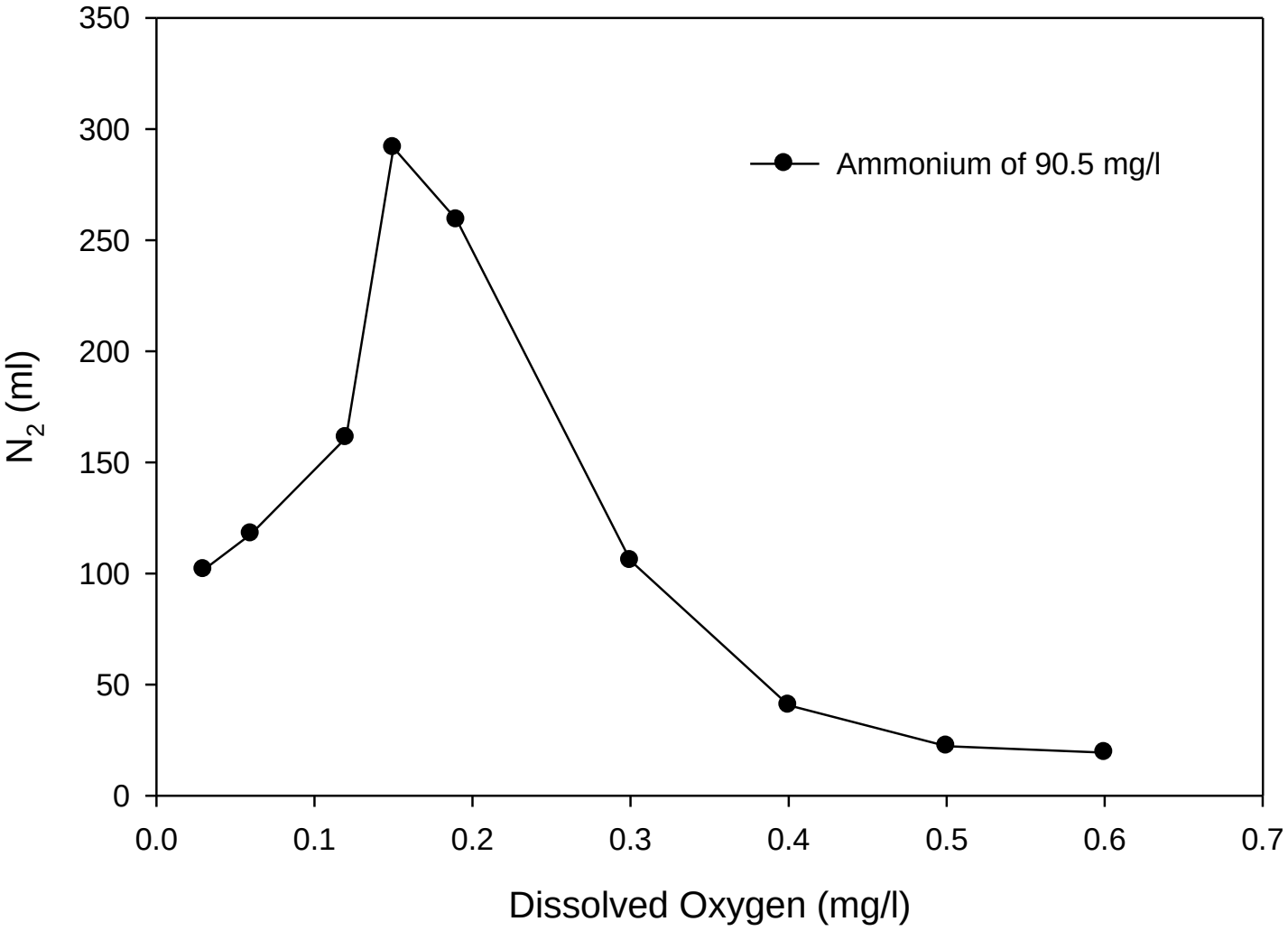
Prior Research — Anammox

Anammox Impacted by Alkalinity

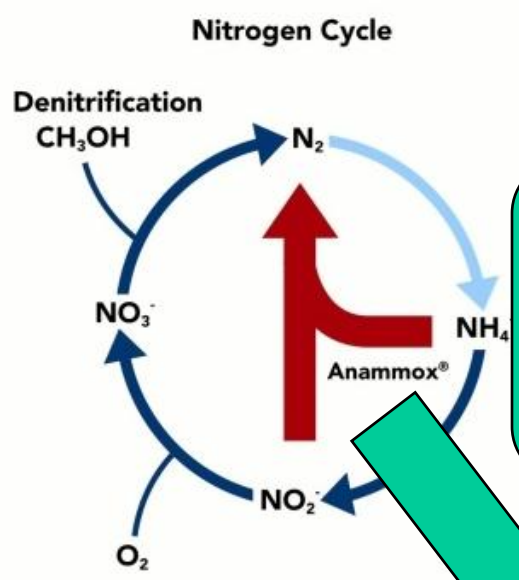


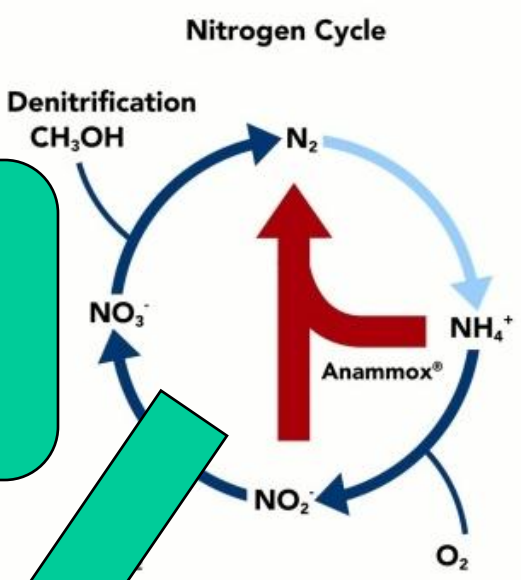
Anammox Impacted by Partial Nitrification

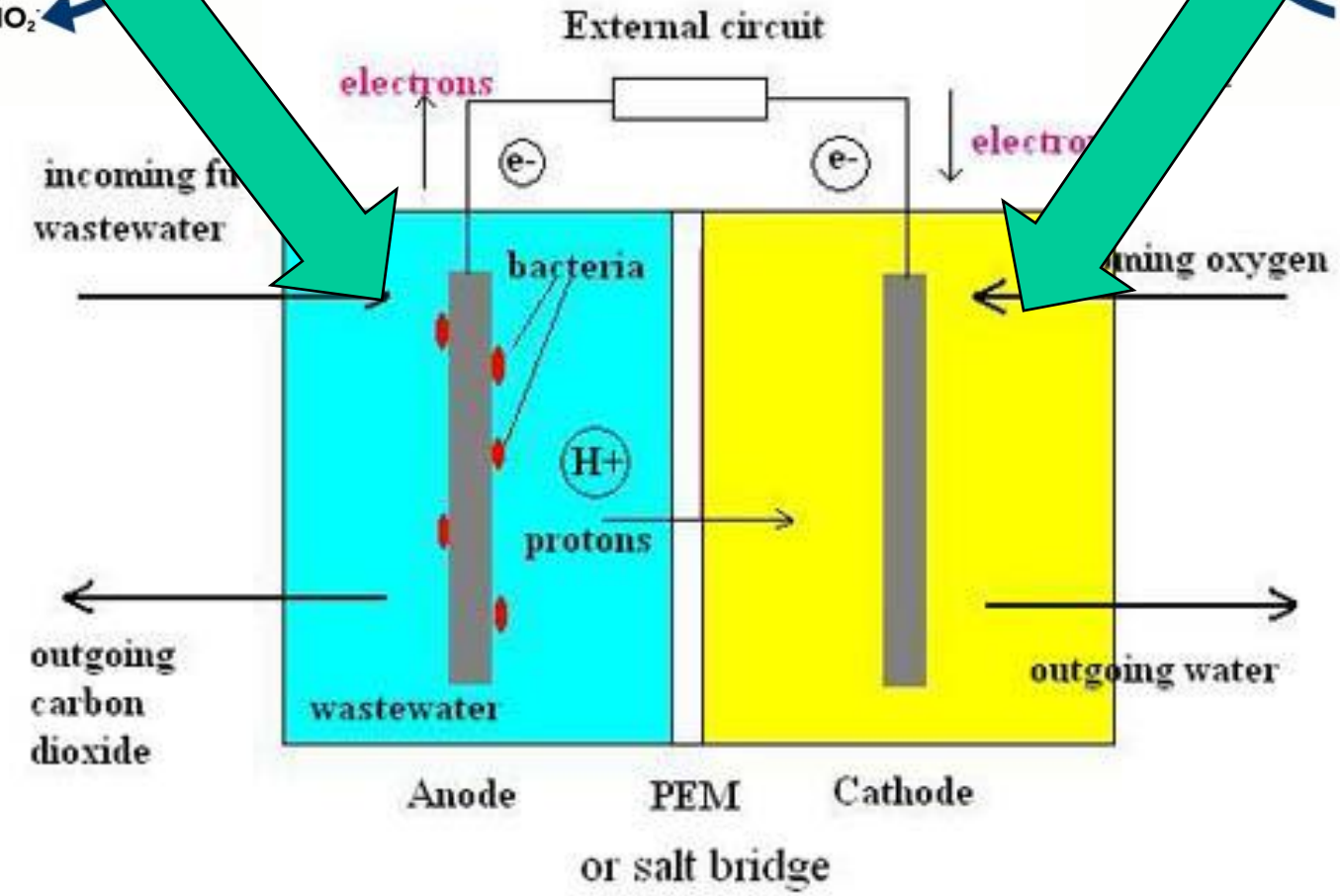


Research Question

Design Bioreactor to Incorporate Anammox into Microbial Fuel Cell







Objectives

- 1. Landfill Leachate Treatment in Ammonium Oxidation/MFC Reactor
- 2. Landfill Leachate Treatment in MFC/Anammox Reactor
- 3. System Comparison in terms of Power Generation as well as Organic Compound Decomposition and Nitrogen Removal

Landfill Soil and Leachate Collection

Leachate was collected from a tank, using a bailer at Franklin County Central Landfill. The leachate tank is located near Monitoring Well MW-19.

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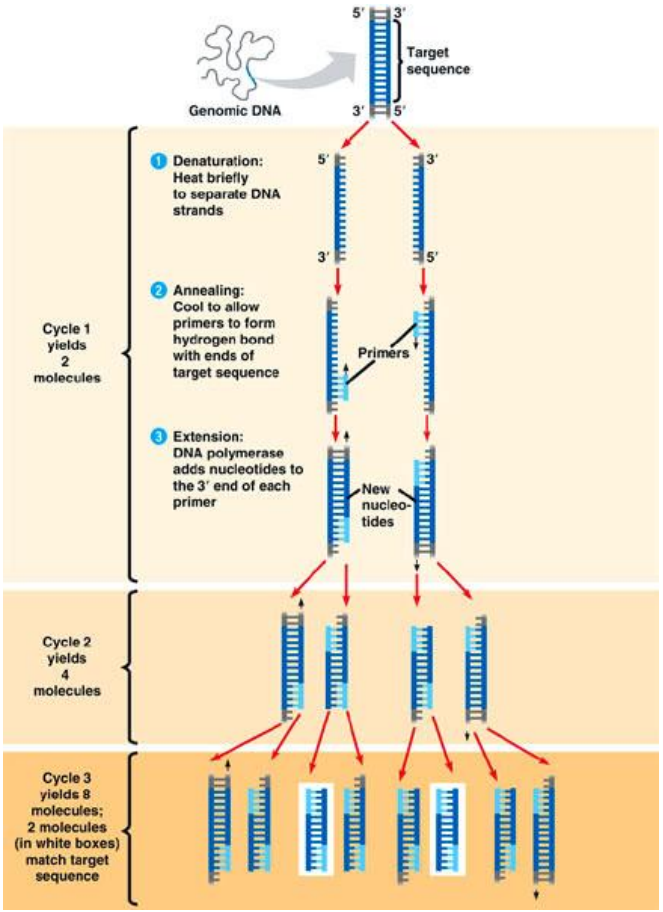
Landfill Leachate Characterization

- BOD_5 up to 20,000 mg/l
- NH_4^+-N up to 500 mg/l
- Phosphorus up to 200 mg/l

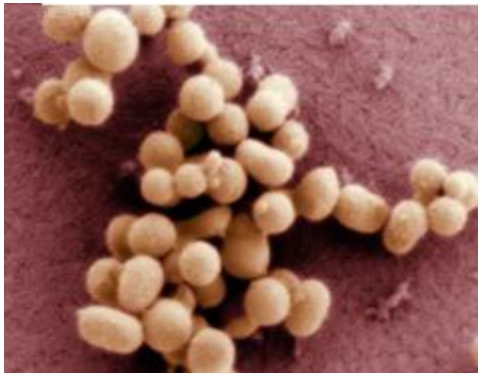
Santa Rosa County
Central Landfill

Perdido Landfill
(Escambia County)

S. putrefaciens and *G. metallireducens* Culturing



polymerase chain reaction



Culturing Media

- KH_2PO_4 160 mg/l
- K_2HPO_4 420 mg/l
- Na_2HPO_4 50 mg/l
- NH_4Cl 40 mg/l
- $MgSO_4 \cdot 7H_2O$ 50 mg/l
- $CaCl_2$ 50 mg/l
- $FeCl_3 \cdot 6H_2O$ 0.5 mg/l
- $MnSO_4 \cdot 4H_2O$ 0.05 mg/l
- H_3BO_3 0.1 mg/l
- $ZnSO_4 \cdot 7H_2O$ 0.05 mg/l
- $(NH4)_6Mo_7O_{24}$ 0.03 mg/l
- Glucose 200 mg/l

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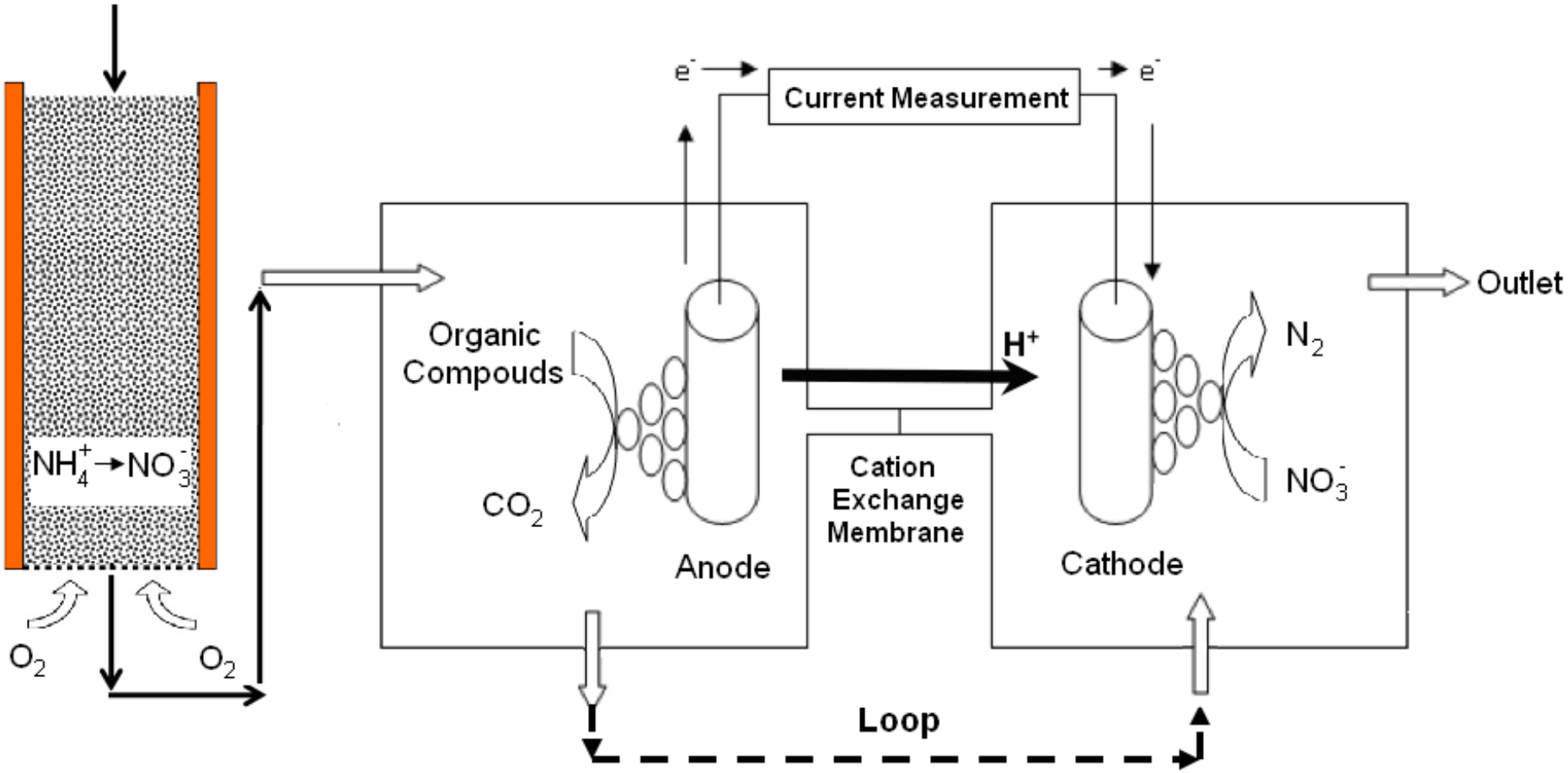
Ammonium Oxidation/MFC Reactor



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Reactor Setup

- Graphite Rod without Catalyst Coating as Anode, Inoculated with *S. putrefaciens*

- Carbon Cloth as Cathode, Inoculated with *G. metallireducens*

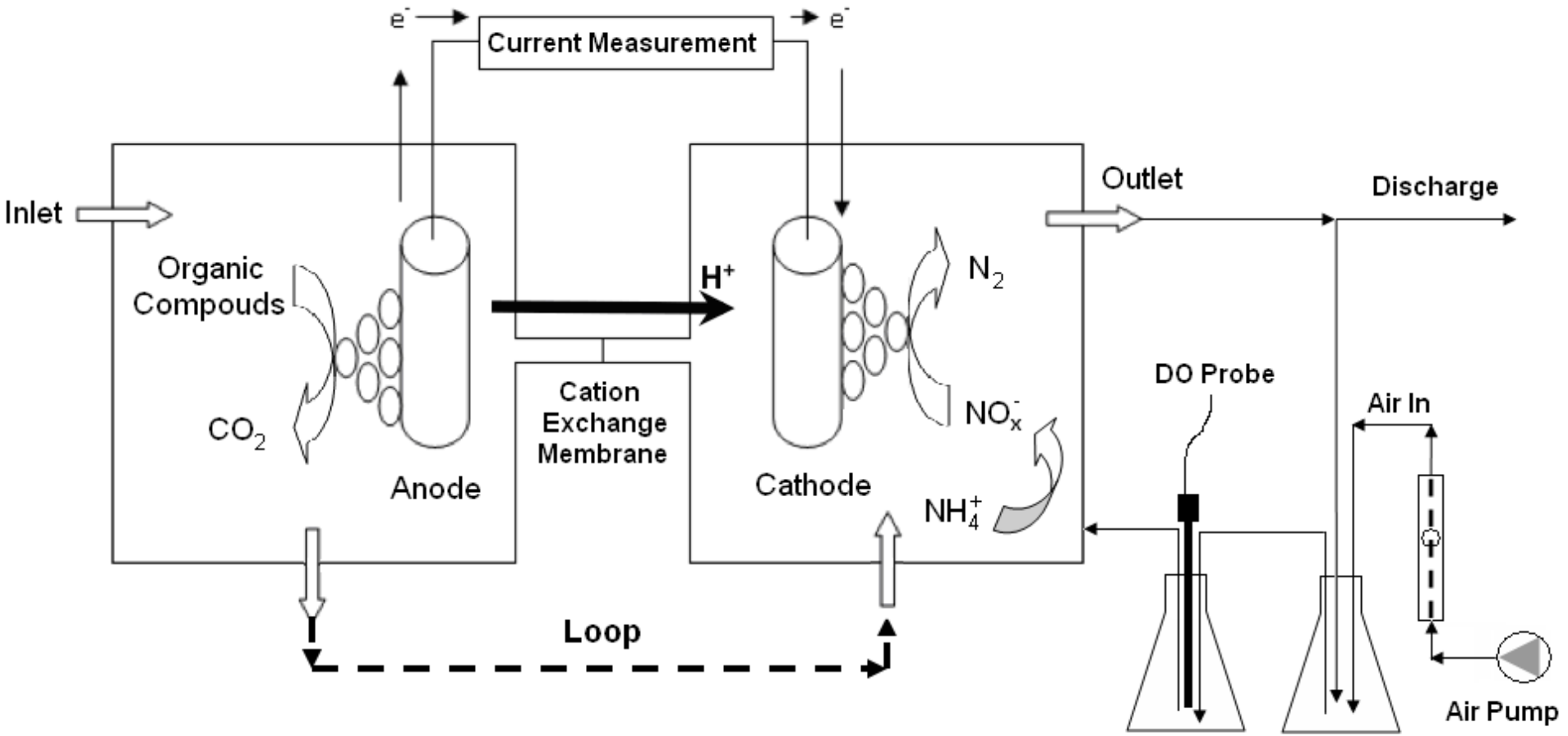
- Synthetic Polymeric Nanoporous Membranes as Cation-Exchange Membrane

- Treated Leachate Looped into Cathodic Chamber

Operation Conditions

- Organic Load (up to 20,000 BOD_5)
- Retention Time (up to 80 hrs)
- pH (4 to 12)
- Alkalinity (up to 500 mg/l as $CaCO_3$)
- Nitrification Reaction Time (up to 2 hrs)

MFC/Anammox Reactor



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Reactor Setup

- Graphite Rod without Catalyst Coating as Anode, Inoculated with *S. putrefaciens*

- Carbon Cloth as Cathode, Inoculated with *G. metallireducens* and Anammox Consortia

- Synthetic Polymeric Nanoporous Membranes as Cation-Exchange Membrane

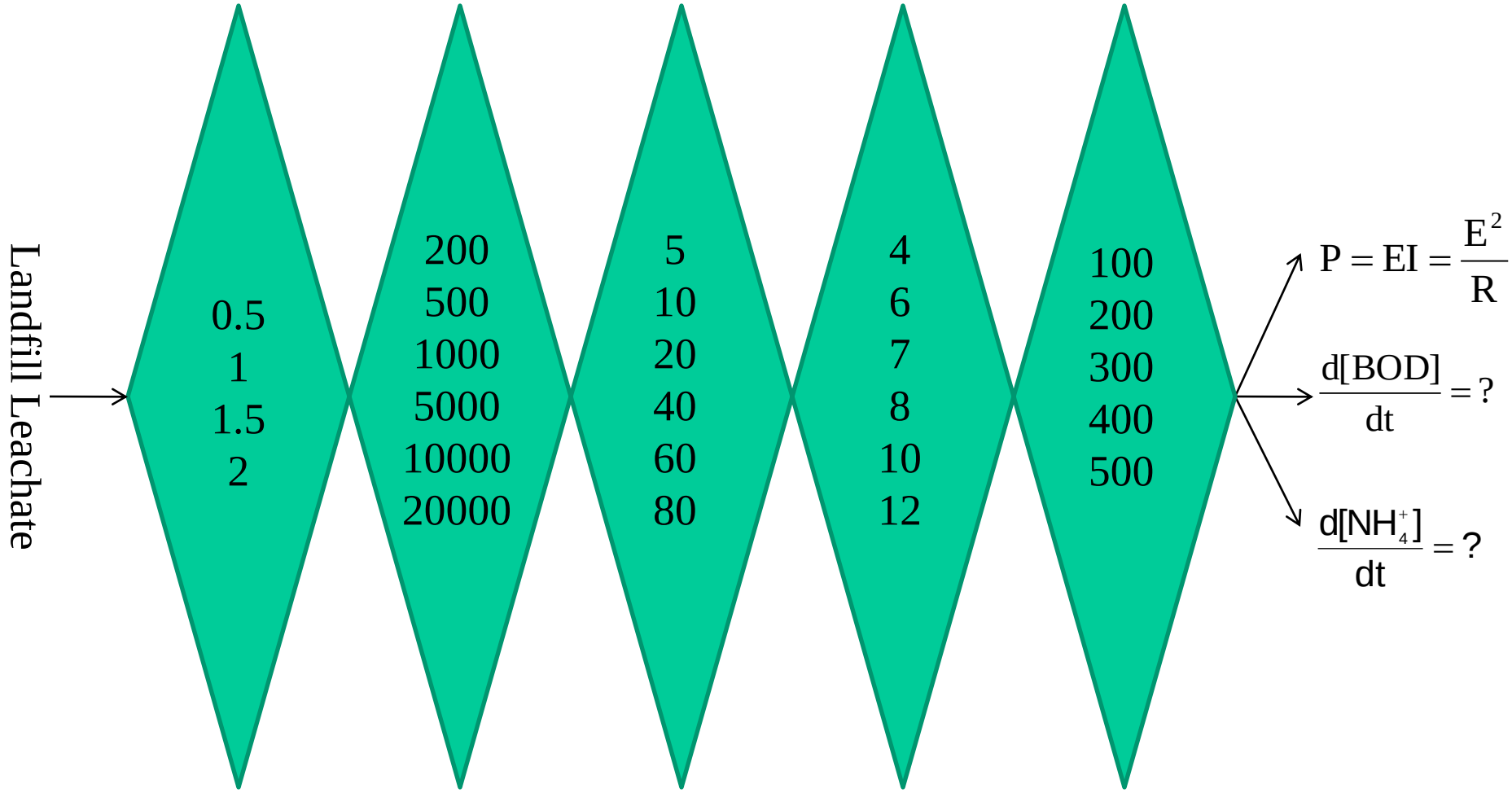
- Treated Leachate Looped into Cathodic Chamber

- Partial Nitrification

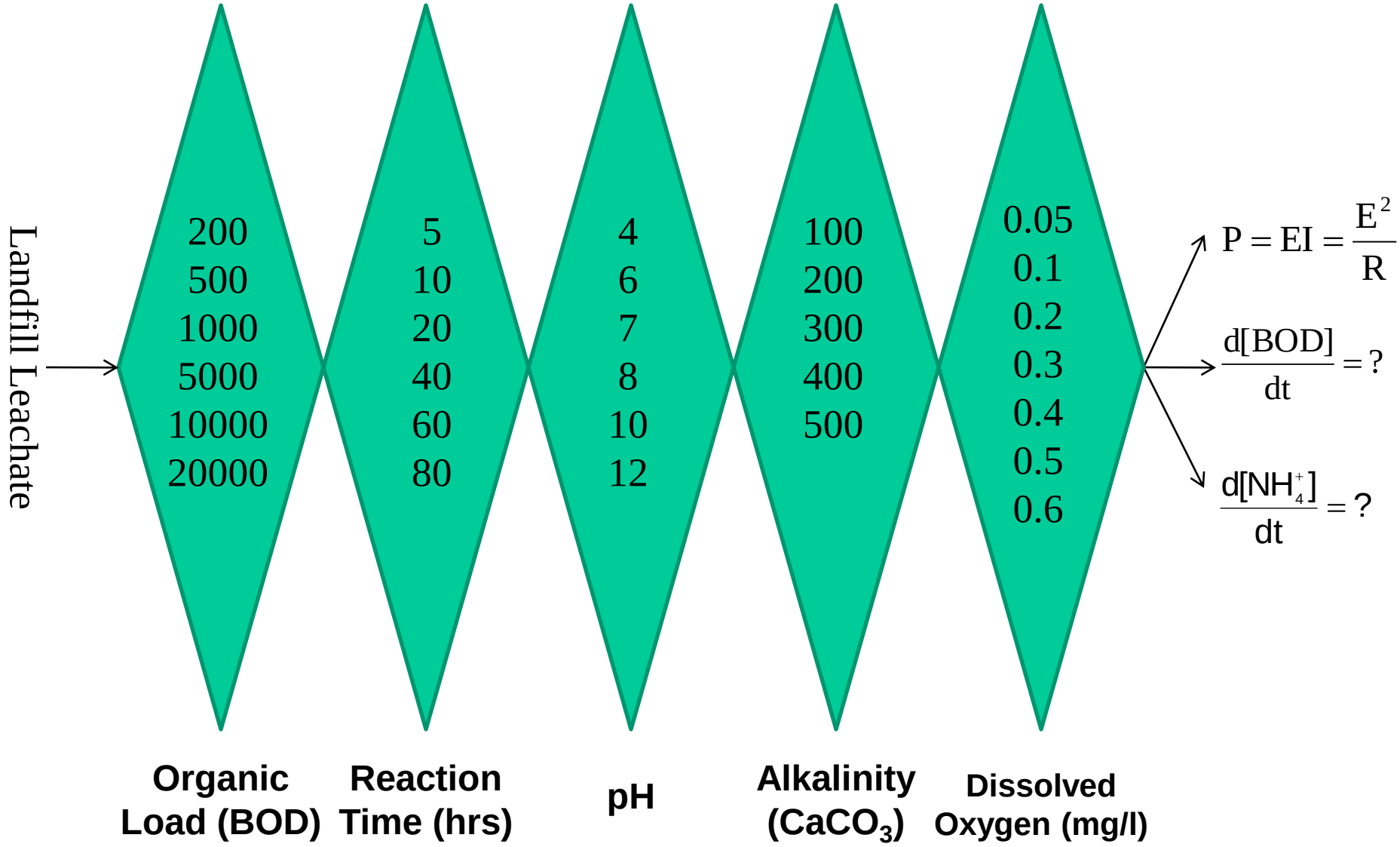
Operation Conditions

- Organic Load (up to 20,000 mg/l BOD_5)
- Retention Time (up to 80 hrs)
- pH (4 to 12)
- Alkalinity (up to 500 mg/l as $CaCO_3$)
- Dissolved Oxygen Concentration (up to 0.60 mg/l)

Expected Results



Expected Results



Power Generation

Current and Power

$$I = \frac{E}{R} \qquad P = EI = \frac{E^2}{R}$$

I: Current

E: Voltage

R: Electrical Resistance

P: Power Output

Organic Decomposition Modeling

Organic Decomposition in MFCs

$$\frac{dS}{dt} = -\frac{\mu_{max} S}{K_m + S}$$

$$S = K_m W\left[\frac{S_0}{K_m} \exp\left(\frac{S_0 - \mu_{max} t}{K_m}\right)\right]$$

$$W(x) + \ln[W(x)] = \ln(x)$$

S: Organic Compound Concentration

K_m: Half Saturation Constant

μ_{max}: Maximum Bacterial Growth Rate

t: Time

S_0: Initial Organic Compound Concentration

W: Lambert Function

Nitrogen Removal Modeling

Ammonium Removal Rate

$$\frac{d[NH_4^+]}{dt} = -\frac{k_r[NH_4^+]}{K_s + [NH_4^+] + [NH_4^+]^2 / K_I}[X]$$

$[NH_4^+]$: Ammonium Concentration t: Time (h)

[X]: Bacterial Cell Concentration K_r: Ammonium Removal Constant

K_s: Half Saturation Constant K_I: Inhibition Constant

System Comparison

- Ammonium Oxidation/MFC Reactor
  - Complete Ammonium Oxidation
  - No Cation Passing through Cation Exchange Membrance
- MFC/Anammox Reactor
  - Ammonium Oxidation Coupled with Denitrification
  - More Power Generation
  - Complicated

Timeline of Milestones

Activity	Month 1- 3	Month 3 - 6	Month 7 – 9	Month 9 - 12
Landfill Leachate and Soil Sample Collection				
S. putrefaciens and *G. metallireducens* Culturing				
Landfill Leachate Treatment in Ammonium Oxidation/MFC Reactor				
Landfill Leachate Treatment in MFC/Anammox Reactor				
System Comparison				
Reporting	Quarterly Report	Quarterly Report	Quarterly Report	Final Report

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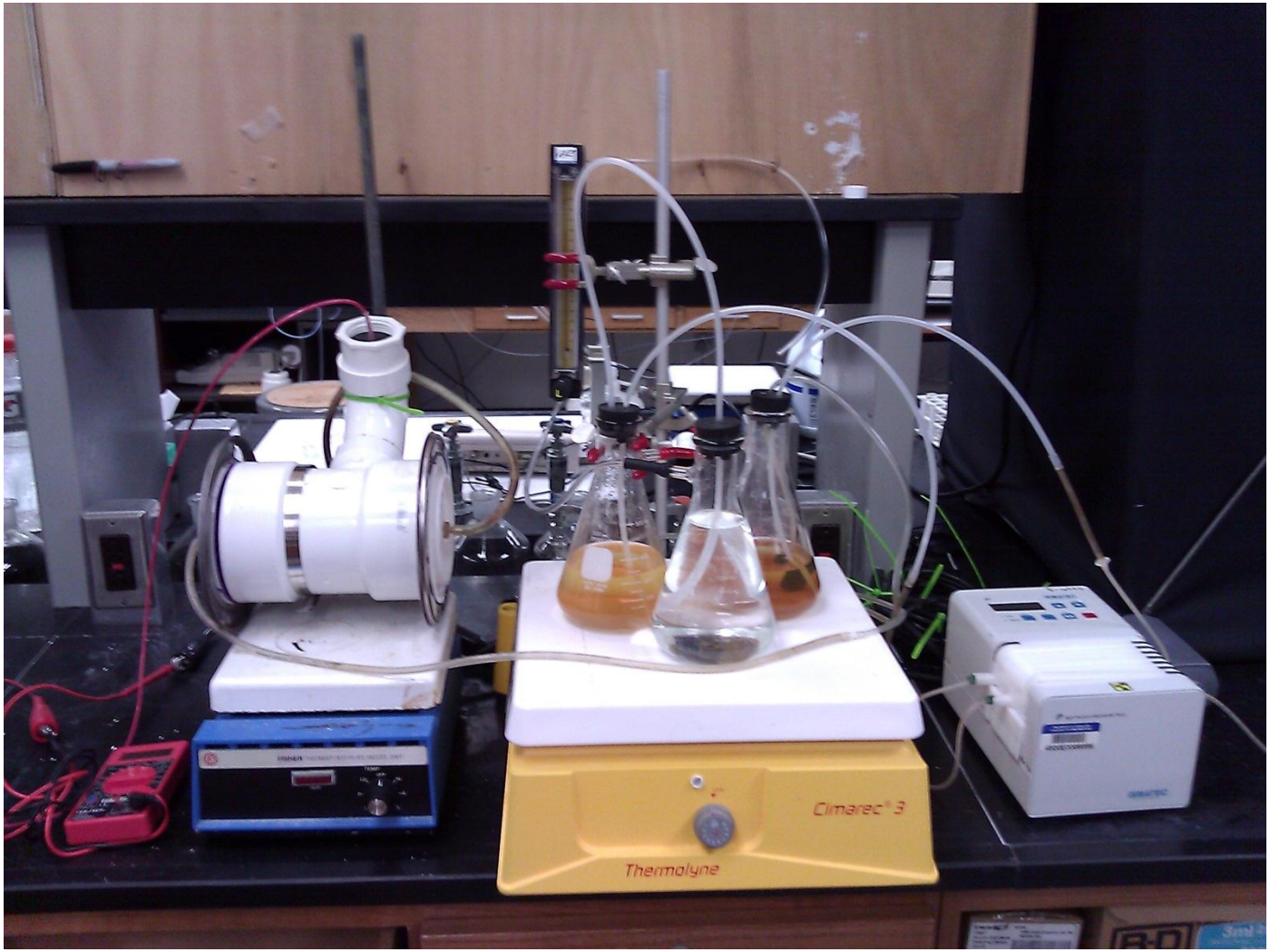
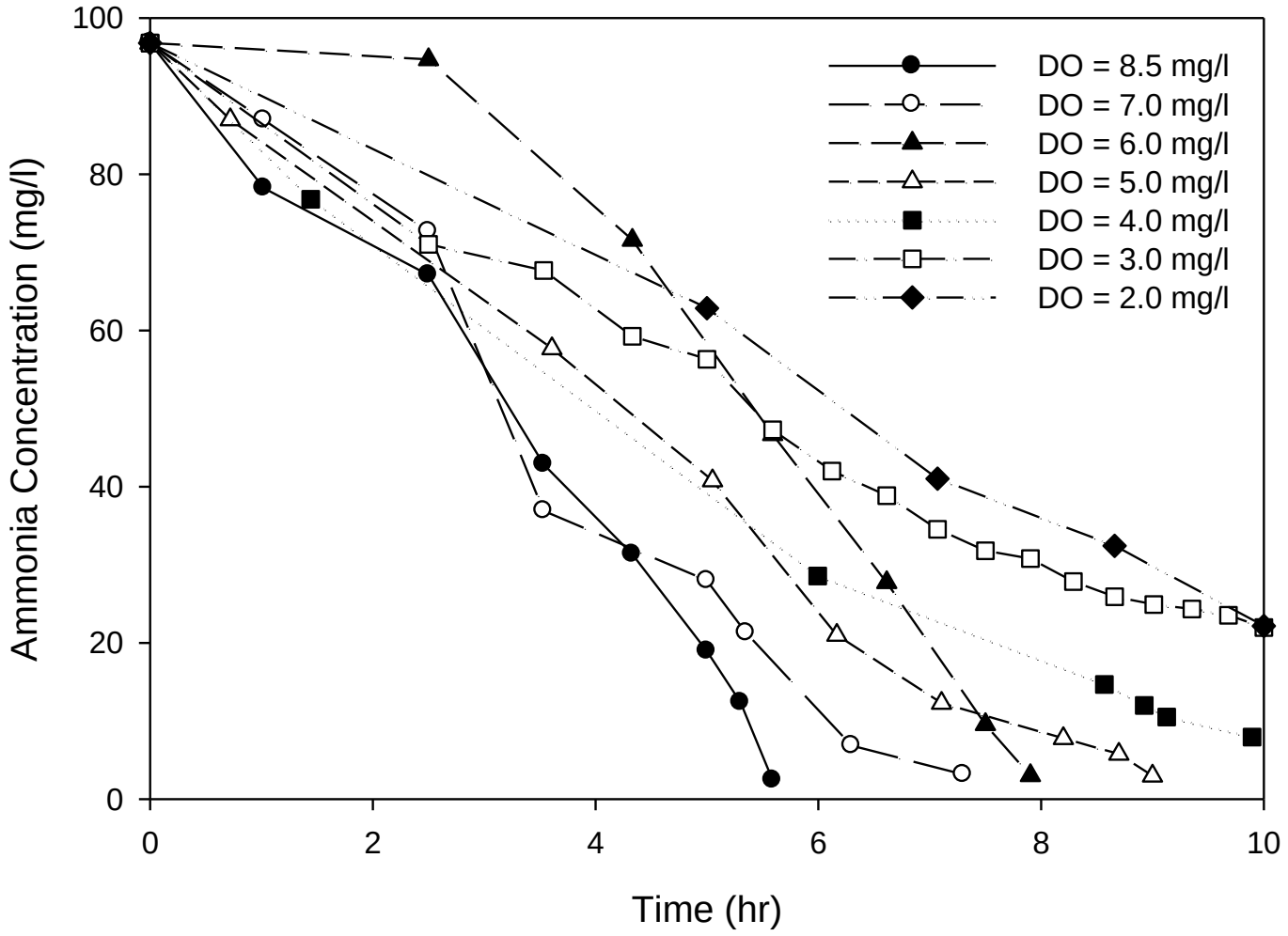
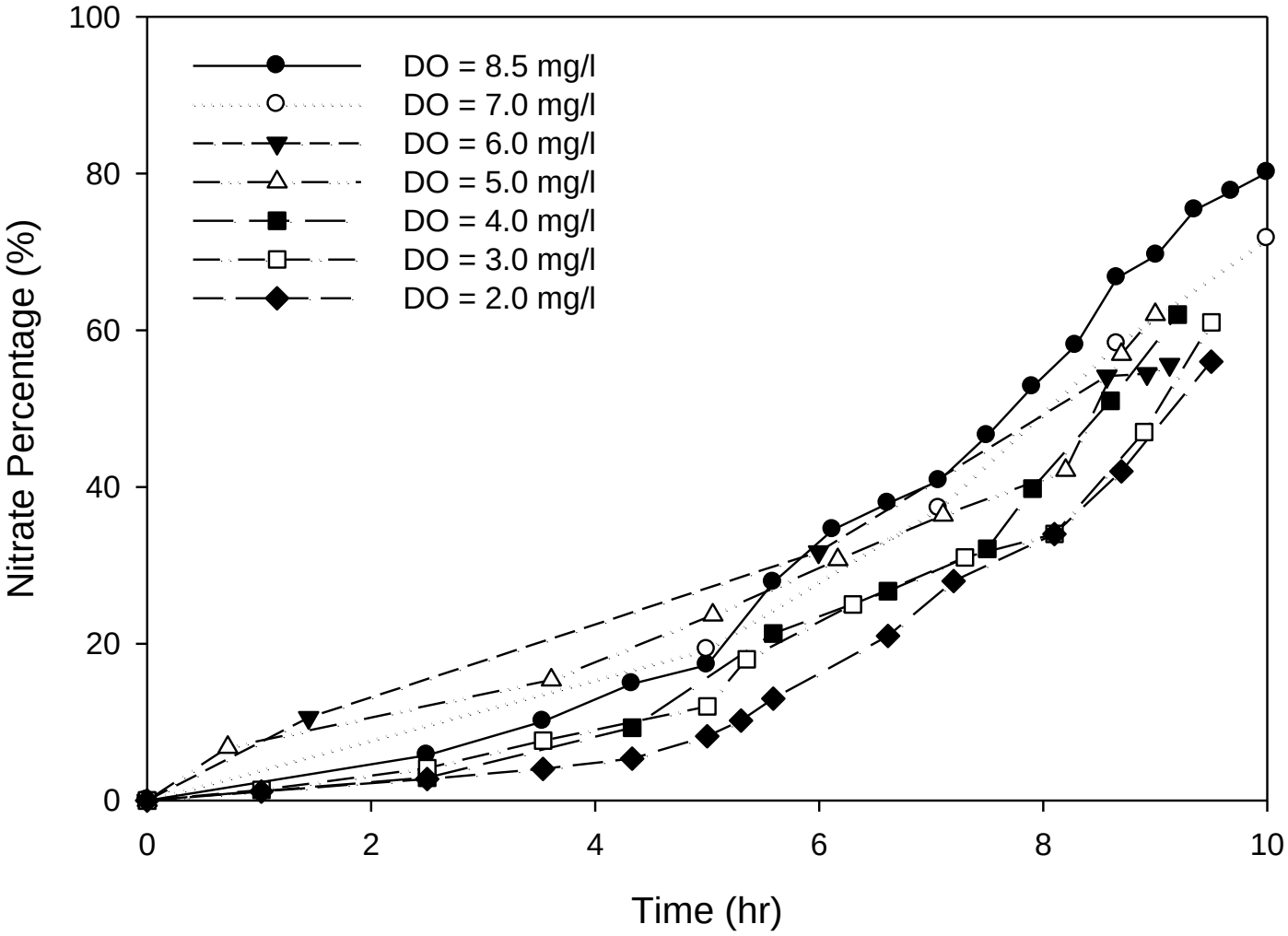
Ammonium Oxidation/MFC Reactor Setup



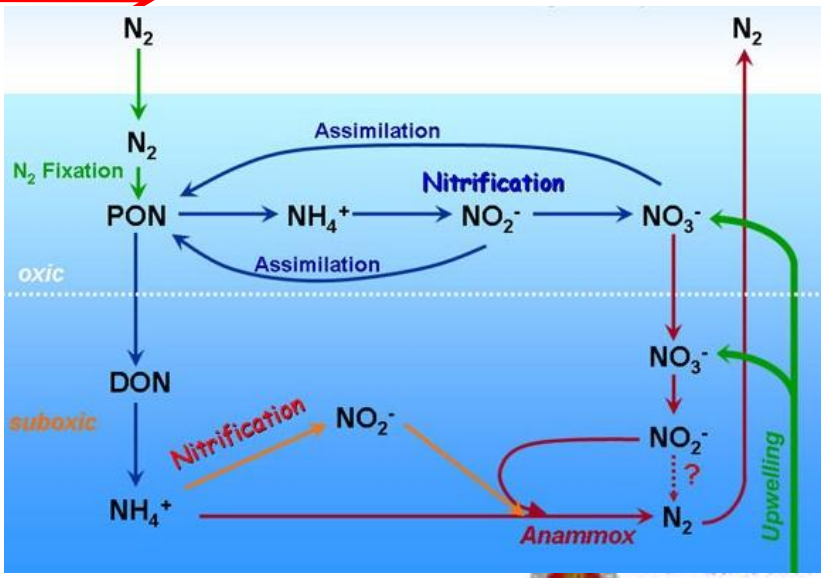
Ammonia Depletion



Nitrate Production



Questions?



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