Technical Advisory Group Meeting

1. “Beneficial Reuse Solutions for Landfill Operations and Management”
4. “Leachate Collection System Clogging”

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Agenda

1. Introductions/Opening Remarks
2. Beneficial Reuse Solutions
3. Electrochemical Oxidation
4. Biosensor for Odor Detection
5. Leachate Collection System Clogging
6. User Input/Open Forum

http://labees.civil.fau.edu/leachate

Introduction

- Biogas can be a potential source of renewable energy
- Directly converted into electricity and fuel
- Can reduce about 4% GHG
- United States has a potential of producing 8 million tonnes /year displacing 5% of current natural gas consumption (NREL 2013)
Objectives

- To test three different ratios (1:2, 1:5, 1:10) for two different waste feedstocks using standard rate mesophilic anaerobic digestion (SRT=7-28 days)

Methodology

- TASK 1: Collect and study food waste samples for preliminary testing
- TASK 2: Bench scale reactor testing
- TASK 3: Ultimate sludge digestibility testing

Identify different types of organic waste

- Food organics - 2,139,230 Tons
- Green waste (Yard waste) - 2,590,265 Tons
- Wastewater treatment plants - 239,500 Tons
- Fats Oils and Greases - 325,980 Tons
- Animal manure - 369,692 Tons

Source: FDEP - 2016

Key Parameters

- The factors affecting the generation of gases (CH₄, H₂S, CO₂) temperature, pH and volume of biogas were being monitored
Technical Advisory Group Meeting, Boca Raton, FL
February 9, 2018

Results - Food Waste

Results - Meat

Results - Primary Sludge (Control)

Task 4. Ultimate Sludge Digestibility

- Digestibility tests were performed using 250 ml borosilicate glass bottles
- Sealed with rubber septum and flushed with nitrogen gas
- Ratio of 1:2, 1:5 and 1:10 for Meat and FOG

- 3 samples for each ratio
  - 72 bottles tested
  - 4 bottles served as seed blanks (only primary sludge)
  - Biogas production and composition, pH measured at each SRT
    - SRT = 7,14,21,28 days

Biogas Production
Next steps

- Run the digester for 21 and 28 days with different slurry ratios and compare the results
- Calculate volatile solids destruction and gas production rate to compare to typical standard rate mesophilic anaerobic digesters
- Monitor VFAs after 28 days

Objectives

1. Conduct testing to determine the efficiency of EOx to remove selected parameters of interest (such as COD/BOD, ammonia, heavy metals, color, turbidity) for safe discharge or reuse of treated leachate
2. Determine if halogenated byproducts are generated during the process
Methodology

1. Perform laboratory scale experiments to assess treatment performance of a 2-stage EOx unit
2. Assess byproduct generation
3. Develop final recommendations and preliminary costs

Test Details

- Anode Range: 10-31 Amps
- Voltage Range: 5 & 7 Volts
- Electrooxidation Time: 75-90 mins
- Sample Volume: 4 liters

Results

- COD Removal
- Ammonia Removal

Sample source: Monarch Hill

Turbidity

EWS:AOx Reactor

Magnei Membrane Reactor
The low removal of COD and ammonia might be because of low initial chlorine concentration. Humic acids may also interfere the treatment process by adsorbing hydroxyl radicals. Humics also acts as photon traps. Zopp et al. stated phenolic group of humics are responsible for this efficiency reduction. Turbidity and color increase during the oxidation process is quite unusual while COD and Ammonia were decreasing. This might have come from the iron bolts used during the experiment.


Task 4: Assess byproduct generation

1. Treating landfill leachate can produce halogenated byproducts like THMs as high as 20,000 ppb, higher than the EPA’s MCL [1]
2. Depending on pH and anode material, the oxidation mechanism follows 2 routes: Electrochemical conversion or electrochemical combustion. By maintaining pH > 7, combustion can be favored, which will generate less halogenated byproducts [2]
3. Later on, generated gas can be trapped and analyzed using GC/MS

Next Steps

1. To determine the optimum chlorine concentration that maximizes removal rate
2. To evaluate ozonation or Fenton as pretreatment
3. To monitor production of halogenated byproducts, such as THMs and HAAS
4. To perform a preliminary cost analysis and comparison with other existing methods

Discussion

1. What is the optimum pH range for getting higher efficiency?
2. How much flow is required in the flow chamber?
3. What is the recirculation rate?

Research Objectives

• To gauge the effect of LFG well age on H2S emission rate
• Present data using air dispersion modeling AERMOD (American Meteorological Society/ Environmental Protection Agency Regulatory Model)

Age Range for LFG Wells

- Young (<1 yr old)
- Medium (1-10 years old)
- Older (>10 years old)

Hypothesis:
- Higher H2S emission rates will be calculated for “young” wells
- H2S emission rates for “older” wells will be relatively stable
Methodology

- Obtain coordinates for at least 6 gas wells in each category (total of 18)
- Collect H2S readings at various distances downwind of wells
- Use a meteorological station to obtain wind speed and stability class
- Use a tape measure to obtain x and H
- Back calculate Q using Gaussian Plume Model

Field Log

- Biosensor Development

Irma Rainfall Increase

Source: NASA's Aqua satellite

Source: National Weather Service
Challenges for Odor Detection

- Ability to deal with environmental conditions (temperature, humidity, etc.)
- Source identification
- Sensitivity at very low (<ppb) levels
- Selectivity of odorants in real mixtures
- Synergistic effects
- Subjectivity
  - Different individual perceptions of odors

State of the Art

Nasal Ranger

Olfactometry

Proposed Solution

- Just like organic constituents in water, there are too many to distinguish
  - So we use a composite test for aggregate organics (i.e. BOD)
- Because people only complain when odors are bad, can we quantify aggregate odorant intensity the same way?
- Use biology as an inspiration
  - Known protein isolates (hOBPIIA) can bind with odorants in the μM-range
  - Odor intensity is based on the number of bound receptors (non-specific?)
  - If so, the spectroscopic tag response will be concentration-dependent and follow Beer’s Law (quantitative)
  - May be reversible too

Turning to Biology as an Inspiration

Mechanism

Odorant binding protein complex

I.
  - Synthesize hOBPIIA using E. coli expression vector (yield = 1.7μg/μL)

II.
  - Apply fluorescent tag (1-AMA) to the protein

III.
  - Perform binding experiments with odorants and mixtures

IV.
  - Determine spectrofluorometry-based concentration-dependence
Prototype Exposure Chamber

Previous Work
- Created prototype biosensor: hOBPIIA + 1-AMA tag complex
- Exposed biosensor to H2S for various times
- Measured intensity of the spectroscopic signal to determine concentration relationship
- Varied concentration to determine detection & quantitation range

Spectrofluorometry Emission

hOBPIIA + 1-AMA complex with exposure to H2S

Saturation Limit
- Model predicts complete saturation at 191 seconds for these conditions:
  - 100 mL of 50 mM K2HPO4/KOH buffered to pH 7.5
  - 1.0 µM hOBPIIA
  - 1.0 µM 1-AMA
  - 25 ppm +/- 5% H2S (balanced with N2)

Max Detection Limit @ 120 seconds
- Signal seems saturated from 5 – 10 µg H2S
- Under these conditions, the maximum quantitation limit appears to be ~4-5 µg H2S

Competitive Spectrofluorometry
- Checked for interference
  - Buffer only
  - Unbound hOBPIIA in buffer
  - Target odorant (H2S) in buffer
  - 1-AMA tag in buffer

Worst Case Scenario
**Competitive Spectrofluorometry**

- No emission detected for any of the biosensor components
  - Buffer only
  - Unbound hOBPIIa in buffer
  - Target odorant (H₂S) in buffer
  - 1-AMA tag in buffer

Interference max @ 485 nm < 2%

**Conclusions & Recommendations**

- hOBPIIa was used for the first time to detect H₂S gas concentrations based on fluorescence intensity

- Since hOBPIIa has a broad binding affinity, it may be used as a biosensor that can measure nuisance odors rapidly in the field

- Experiments exposing the system to higher concentrations of H₂S will reveal the Beer’s Law quantitation range

- Then validation tests can be conducted to see if the calibration is accurate

- A more precise means of collecting samples from the reaction chamber should be developed

- Following the success of H₂S, the next step is to experiment with other odorants, gas mixtures and field samples common to MSW facilities

**Upcoming Work**

- Teaming up with Dr. Binninger (FAU-Biology)
- Testing the biosensor configuration
  - Fluorophore tag (1-AMA)
  - Monoclonal antibody
  - Positive vs. inverse response (bound vs. unbound)
  - Confirm quantitation accuracy
- Managing spectral interferents, if any
  - Quenching
  - Raman scattering
- Effectiveness with other specific odorants and mixtures
  - Concentration range for detection/quantitation
  - Flow rate and reversibility

**Goal**

- Verify the success of H₂S, the next step is to experiment with other odorants, gas mixtures and field samples common to MSW facilities

**Still Need Comments**

- Odor complaint log form
- Anything missing?
- Anything should be removed?
- Will you agree to try it out and let us know how you like it?
- Please forward it to your colleagues and give us feedback

**Still Need Comments**

- Odor Threat Assessment
  - Wind speed/direction
  - Dew point
  - Precipitation
  - Atmospheric stability class
  - Delta pressure

- Will you agree to try it out and let us know how you like it?
  - Please forward it to your colleagues and give us feedback
"Investigation of Leachate Management Solutions at the Solid Waste Authority of Palm Beach County"

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Background

Pipe Network (40’x20’)

Agenda

• Current work (Tasks 1-5)
• Results
• Future work

Task 1. Impacts of Flow Regime on Geochemical Rocking

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>pH</th>
<th>Field Cond. (mS/cm)</th>
<th>TDS (g/L)</th>
<th>CaCO₃ (CaCO₃ mg/L)</th>
<th>Ca (CaCO₃ mg/L)</th>
<th>TDS (g/L)</th>
<th>Temp. (ºC)</th>
<th>LSI</th>
<th>RI</th>
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<tbody>
<tr>
<td>MH 6</td>
<td>7.26</td>
<td>39.29</td>
<td>18.90</td>
<td>4,820</td>
<td>1,550</td>
<td>22.19</td>
<td>33.11</td>
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<td>MH 10</td>
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<td>36.10</td>
<td>18.30</td>
<td>5,200</td>
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<td>20.13</td>
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<td>PS/B</td>
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<td>30.80</td>
<td>15.30</td>
<td>4,810</td>
<td>3,280</td>
<td>18.85</td>
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<td>1,420</td>
<td>14.76</td>
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<td>DIW</td>
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<td>970</td>
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<td>0.68</td>
<td>28.70</td>
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<td>4.8</td>
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<td>Deep well</td>
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<td>NEFCO</td>
<td>5.79</td>
<td>7.42</td>
<td>1.97</td>
<td>500</td>
<td>530</td>
<td>4.04</td>
<td>35.11</td>
<td>0.6</td>
<td>7.0</td>
</tr>
</tbody>
</table>

Average water quality parameters from 5 sampling events

- Water quality did not change from 2013-2016 study
- NEFCO wastewater is helping to reduce scaling in the injection well due to low pH
- More likely that groundwater dilution reduces precipitation potential from flushing effect
Task 2. Impacts of Biological Activity as a Clogging Trigger Mechanism

- UV disinfection unit has been recommended and purchased

Lab test:

<table>
<thead>
<tr>
<th>Distance from the well surface, cm</th>
<th>Spectrum Fluence (mJ/cm²)</th>
<th>UV-C</th>
<th>UV-254</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>122</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>3.55</td>
<td>9.7</td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>7.25</td>
<td>2.1</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>12.5</td>
<td>0.9</td>
<td>0.1</td>
<td></td>
</tr>
</tbody>
</table>

Lab test:

- ≤ 3-log reduction

Lab experiments with carbon dioxide gas
- Feeder pump has been recommended

Lab setup:

- Capacity: up to 170 GPD

Task 3. Impacts of pH adjustment for Enhanced Precipitate Control

- Lab experiments with carbon dioxide gas
- Feeder pump has been recommended

Laboratory setup:

- Materials:
  1. Calibration gas (H₂)  
  2. Calibration gas (CO₂:40%-59%-CO)  
  3. A transparent plastic bottle (Ø)  
  4. Regulator (2)  
  5. Gas mixing valve (Ø)  
  6. Sampling port (Ø)  
  7. Alkaline filter (Ø)  
  8. Building drugs (Ø)
Task 3 Lab Experiments with Carbon Dioxide Gas – Effect on pH

pH changes over time

- Increase in pH results in higher LSI
- LFG decreases LSI

Time, min | pH | TDS (g/L) | Alk. (mg/L | CaCO3) | Ca, (mg/L | CaCO3) | Temp., ºC | pHs LSI RI
---|---|---|---|---|---|---|---|---
Control (N2)
0 | 7.48 | 6.98 | 3600 | 900 | 18.2 | 5.7 | 1.7 | 4.0
30 | 7.71 | 7.00 | 1300 | 1700 | 15.5 | 6.0 | 1.8 | 4.2
60 | 7.83 | 6.93 | 1200 | 1200 | 15.2 | 6.1 | 1.7 | 4.5
100 | 7.91 | 7.02 | 1500 | 1700 | 16.5 | 5.9 | 2.0 | 3.8
120 | 7.91 | 7.00 | 1100 | 1100 | 16.8 | 6.2 | 1.7 | 4.5
LFG
0 | 7.48 | 6.98 | 3600 | 900 | 18.2 | 5.7 | 1.7 | 4.0
30 | 6.70 | 7.07 | 1400 | 1200 | 13.4 | 6.1 | 0.6 | 5.5
60 | 6.65 | 7.19 | 1400 | 1200 | 14.3 | 6.1 | 0.6 | 5.5
100 | 6.65 | 7.12 | 1300 | 1400 | 16.0 | 6.0 | 0.6 | 5.4
120 | 6.57 | 7.14 | 1300 | 1200 | 16.4 | 6.1 | 0.5 | 5.6
Air
0 | 7.48 | 6.98 | 3600 | 900 | 18.2 | 5.7 | 1.7 | 4.0
30 | 7.82 | 7.06 | 800 | 1100 | 12.6 | 6.4 | 1.4 | 5.0
60 | 7.85 | 7.04 | 1300 | 1700 | 13.7 | 6.0 | 1.9 | 4.1
100 | 8.02 | 7.01 | 1700 | 1300 | 15.1 | 6.0 | 2.1 | 3.9
120 | 8.03 | 7.02 | 1200 | 1200 | 15.5 | 6.1 | 1.9 | 4.3

Task 3 Lab Experiment results summary

- Increase in pH results higher LSI
- LFG decreases LSI
Future Work

• Task 1. Impacts of Flow Regime on Geochemical Rocking
  • Experiments with varying Reynold’s Number and flow depth in leachate bleed test using side by side pipe network
  • A mass balance analysis to determine the effect of NEFCO water (lab or field test if possible)

• Task 2. Impacts of Biological Activity as a Clogging Trigger Mechanism
  • Lab experiments with a small scale UV disinfection unit
  • Microscopic morphological analysis (Desulfo vibrio is comma shaped)
  • Perform a leachate bleed test using side by side pipe network
  • Microbiology and mineral testing

• Task 3. Impacts of pH adjustment for Enhanced Precipitate Control
  • Water quality analysis
    - pH, conductivity, TDS, calcium, alkalinity, temperature, sulfides, sulfates, buffering capacity
  • Several different feed rates of hydrochloric acid in leachate bleed test using side by side pipe network
    - 15 - 150 gpd HCl, antiscalant, and LFG (CO2) addition
  • Water quality and mineral testing
  • Goal is to create guidance for acid addition

• Task 4. Impacts to the Deep Injection Well
  • FAU will monitor the flows and loadings with data beyond March 2017
  • FAU is working with 802240/100 to determine biofilm microbiology and chemotaxy
  • FAU will investigate the new dilution system added to the east side gravity leachate collection system as part of Task 1 activities

• Task 5. Perform other tasks for SWA as requested by SWA
  • FAU will investigate the new dilution system added to the east side gravity leachate collection system as part of Task 1 activities

Thank you

Questions???