Florida Atlantic University
College of Engineering & Computer Science

## Technical Advisory Group Meeting

1. "Beneficial Reuse Solutions for Landfill Operations and Management"
2. "Investigation of Electrochemical Oxidation for Treatment of Landfill Leachate"
3. "Detection of Nuisance Odors Using Odor Binding Protein Sensor & Development of a Biosensor for Measuring Odorants in the Ambient Air Near Solid Waste Management"
4. "Leachate Collection System Clogging"

**Daniel E. Meeroff, Ph.D.**
Department of Civil, Environmental & Geomatics Engineering

*Technical Advisory Group Meeting ▫ February 9, 2018 ▫ Boca Raton, FL*

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## Agenda

| | |
|---|---|
| 1. Introductions/Opening Remarks | *Dr. Meeroff* |
| 2. Beneficial Reuse Solutions | *Sethi/Quddus/de Almeida/King* |
| 3. Electrochemical Oxidation | *Salek* |
| 4. Biosensor for Odor Detection | *Binninger/Martinez* |
| 5. Leachate Collection System Clogging | *Shaha* |
| 5. User Input/Open Forum | *Everyone* |

*Technical Advisory Group Meeting, Boca Raton, FL*
*February 9, 2018*

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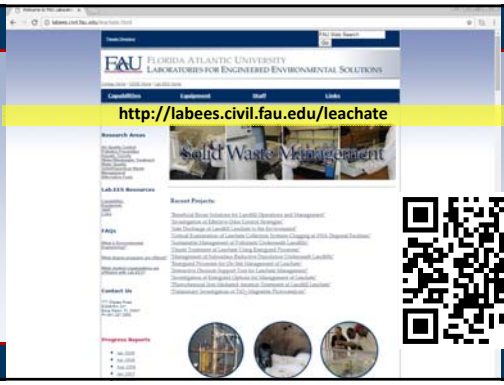


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*Technical Advisory Group Meeting, Boca Raton, FL*
*February 9, 2018*

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## "Beneficial Reuse Solutions for Landfill Operations and Management"

**Rohan Sethi**
Department of Civil, Environmental & Geomatics Engineering

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## 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)

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## 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)




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## Methodology

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



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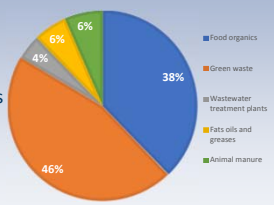
## Identify different types of organic waste

- 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



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## TASK 1:Collecting Meat and FOG samples

- Seed (4% solids, primary sludge) was obtained from the Boca Raton utility services
- FOG collected from Broward County water and wastewater services at the transfer storage station
- Meat waste and other food organic samples from primary generators were collected from a third party hauler



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## TASK 2. Preliminary Bench Scale reactor testing



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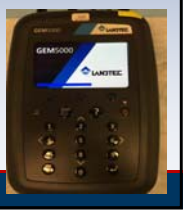
## Key Parameters

- The factors affecting the generation of gases ($CH_4$,$H_2S$,$CO_2$) temperature, pH and volume of biogas were being monitored



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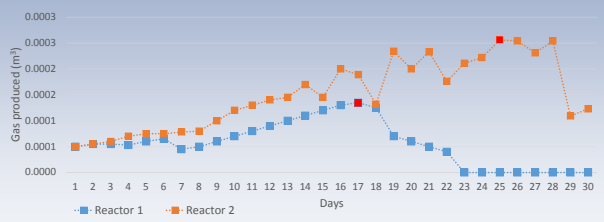
## Results- Food Waste



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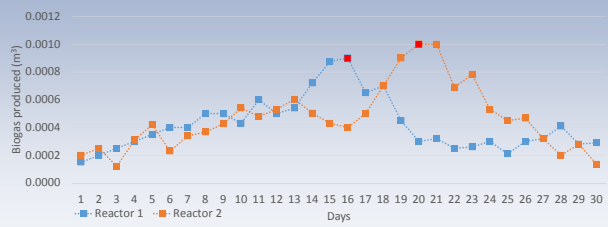
## Results- Meat



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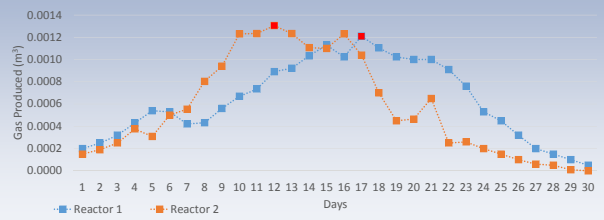
## Results- Primary Sludge (Control)



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## 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




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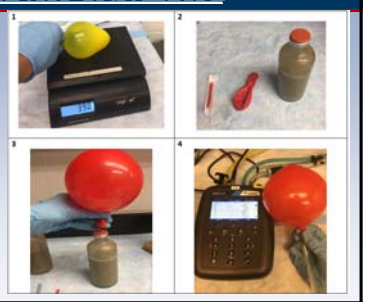
- 3 samples for each ratio
  - 72 bottles tested
- 4 bottles served as seed blanks (only primary sludge)
- Biogas production and composition, pH measured at each SRT
  - SRT = 7,14,21,28 days



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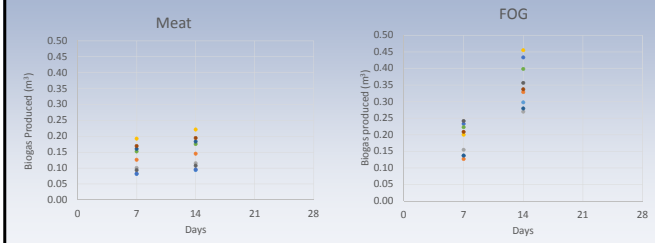
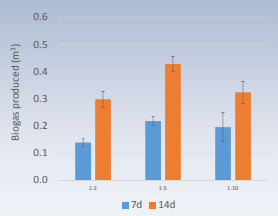
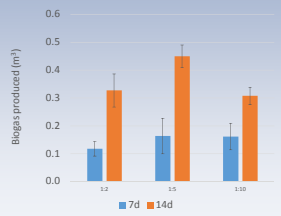
## Biogas Production



## Meat




## FOG








## 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









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## "Landfill Leachate Treatment by Advanced Electrochemical Oxidation"

**Md Fahim Salek**

**Advisor: Dr. Daniel Meeroff**



## Introduction

- **Electrochemical oxidation (EOx) involves direct oxidation of pollutants at the anode as well as indirect oxidation by hydroxyl radical, chlorine, hypochlorite ion, and other secondary oxidants**
- **EOx seems promising for removal of COD, ammonia, and other contaminants from leachate**
- **Recently, EOx has been successfully used for treating wastewater from tanneries, power plants, and landfills**





## 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**

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## 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



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## Task 1: Collect data on electrochemical oxidation

| Anode Material | Current Density ($Am^{-2}$) | Volume of Sample (L) | Time (h) | COD Removal % | Ammonia Removal % | $Cl^-$ mg/l | Authors |
|---|---|---|---|---|---|---|---|
| Ti/RuO2-IrO2 | 260 A m-2 | 0.2 | 1.5 | 44 | 50 | 831 | H. Zhang et. Al (2011) |
| Ti/IrO2-RuO2 | 80 A m-2 | 0.12 | 4 | 20 | N/A | 6150 | E. Turro et. Al (2011) |
| | 160 A m-2 | | | 40 | | | |
| | 320 A m-2 | | | 35 | | | |
| Ti/RuO2-IrO2 | 300 A m-2 | 0.8 | N/A | 20 | 35 | 3702 | H. Zhang et. Al (2011) |
| | 900 A m-2 | | | 10 | 85 | | |
| Graphite carbon | 800 A m-2 | 0.5 | 4 | 65 | N/A | N/A | M. Bashir et. Al (2009) |
| BDD | 2571 A m-2 | 10 | 8 | 50 | 30 | 2574 | A. Anglada et. Al (2011) |
| Ti/Pt | 400 A m-2 | 0.25 | 1 | 63 | 80 | 5500 | F. Feki et. Al |



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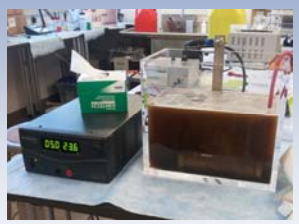
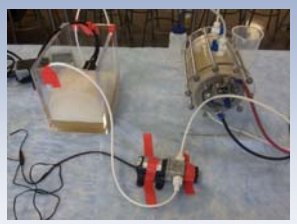
## Experimental Set-up



EWS:AOx Reactor



Magneli Membrane Reactor



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## Test Details

| Batch Reactor | |
|---|---|
| Ampere Range | 19-31 Amps |
| Voltage Range | 5 & 7 Volts |
| Electrooxidation Time | 75-90 mins |
| Anode Material | Titanium connected using steel nuts and bolts |
| Sample Volume | 4 liters |

| Flow Reactor | |
|---|---|
| Ampere Range | 17-23 Amps |
| Voltage Range | 4.7 & 6 Volts |
| Electrooxidation Time | 75 mins |
| Anode Material | Titanium coated with IrOx and RuOx |
| Flow | 4 liters/min |
| Sample Volume | 4 liters |



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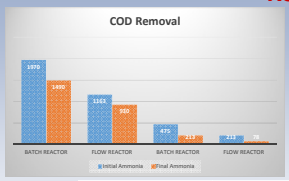
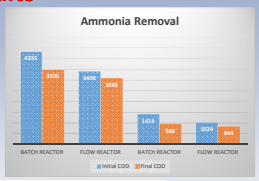
## Results




| | Sample Source | Removal Efficiency |
|---|---|---|
| COD Removal | Monarch Hill | 52% |
| | SWA | 83% |
| Ammonia Removal | Monarch Hill | 28% |
| | SWA | 40% |



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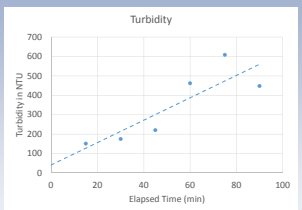
## Results

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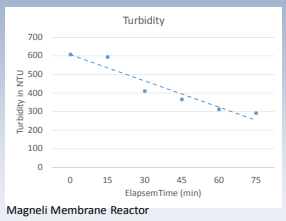


Magneli Membrane Reactor

Sample source: Monarch Hill

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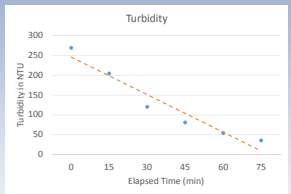
## Results

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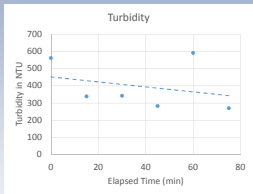


Magneli Membrane Reactor

Sample source: SWA



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## Results

- The low removal of COD and ammonia might be because of low initial chlorine concentration[1] [2]
- Humic acids may also interfere the treatment process by adsorbing hydroxyl radical.[3] Humics also acts as photon traps. Zepp at al. stated phenolic group of humic 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

[1] Chiang, L.C., Chang, J.E. and Chung, C.T., 2001. Electrochemical oxidation combined with physical–chemical pretreatment processes for the treatment of refractory landfill leachate.
[2] Li, L. and Liu, Y., 2009. Ammonia removal in electrochemical oxidation: mechanism and pseudo-kinetics.
[3] Konstantinou I.K., Zarkadis A.K., Albanis T.A. and Triantafyllos A. (2001). Photodegradation of selected herbicides in various natural waters and soils under environmental conditions. J. Environ. Qual. 30, 121-130.



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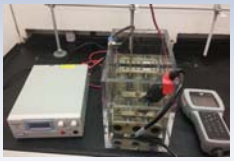
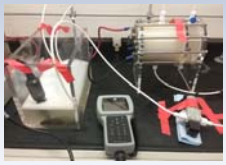
## Task 2: Perform laboratory scale experiments

- A synthetic COD solution was prepared by adding KHP, NaCl and $NaHCO_3$ to deionized water to assess COD removal efficiency
- The prepared solution was treated in an open electrochemical oxidation chamber for 1 hour
- After that, the solution went through a closed electrochemical oxidation chamber for 1 hour







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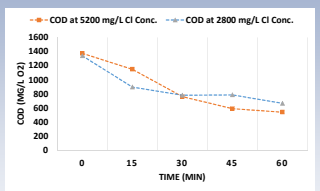
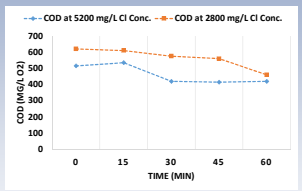
## Task 3: Assess treatment performance




EWS:AOx Reactor




Magneli Membrane Reactor



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## Task 3: Assess treatment performance

| Chloride Conc. | Reactor | Removal Efficiency | Removal Rate |
|---|---|---|---|
| 5200 mg/l Cl | Batch Reactor | 60.3% | 2.30 mg/L-min |
| | Flow Reactor | 18.4% | 0.26 mg/L-min |
| 2800 mg/l Cl | Batch Reactor | 50% | 1.86 mg/L-min |
| | Flow Reactor | 25.8% | 0.44 mg/L-min |



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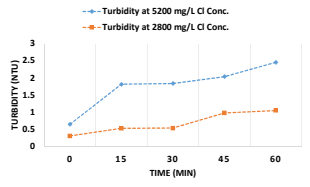
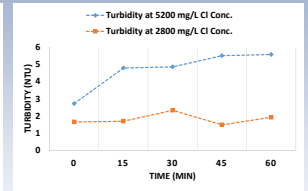
## Task 3: Assess treatment performance




EWS:AOx Reactor




Magneli Membrane Reactor

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## 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

[1] Li, Nanzhu & Deng, Yang. (2012). Formation of Trihalomethanes (THMs) during Chlorination of Landfill Leachate. International Journal of Environmental Pollution and Remediation. . 10.11159/ijepr.2012.002.
[2] A. Anglada, A. Urtiaga, I. Ortiz, Contributions of electrochemical oxidation to wastewater treatment: fundamentals and review of applications, Journal of Chemical Technology and Biotechnology 84 (2009) 1747-1755



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## 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 HAA5**
4. **To perform a preliminary cost analysis and comparison with other existing methods**



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## 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?**



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**Monitoring and Modeling to Estimate Impact of Hydrogen Sulfide Emissions and Dispersion**

**Lab.EES Director: Dr. Meeroff**

**Undergraduate Research Assistant: Angel Martinez**

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## Research Objectives

- **To gauge the effect of LFG well age on $H_2S$ emission rate**
- **Present data using air dispersion modeling AERMOD (American Meteorological Society/ Environmental Protection Agency Regulatory Model)**



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## Age Range for LFG Wells

| Young | Medium | Older |
|---|---|---|
| •<1 yr old | •1-10 years old | •>10 years old |

Hypothesis:
- Higher $H_2S$ emission rates will be calculated for "young" wells
- $H_2S$ emission rates for "older" wells will be relatively stable

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### Methodology

- Obtain coordinates for at least 6 gas wells in each category (total of 18)
- Collect $H_2S$ 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

$$C(x,y,z) = \frac{Q}{2\pi u \sigma_y \sigma_z} \times \left[\exp\left(-\frac{y^2}{2\sigma_y^2}\right)\right]\left[\exp\left(\frac{-(z-H)^2}{2\sigma_z^2}\right) + \exp\left(\frac{-(z+H)^2}{2\sigma_z^2}\right)\right]$$

C = Concentration of the chemical in air. $[ML^{-3}]$
Q = Rate of chemical emission. $[M/T]$
u = Wind speed in x direction. $[L/T]$
$\sigma_y$ = Standard deviation in y direction. [L]
$\sigma_z$ = Standard deviation in z direction. [L]
y = Distance along a horizontal axis perpendicular to the wind. [L]
z = Distance along a vertical axis. [L]
H = Effective stack height. [L]



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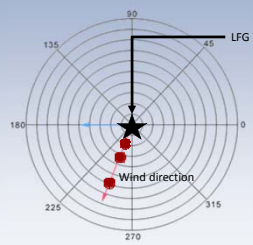
### Methodology







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### Field Log




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### Irma Rainfall Increase


Source:(National Weather Service)

Source: NASA's Aqua satellite



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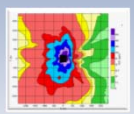
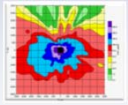
### Methodology

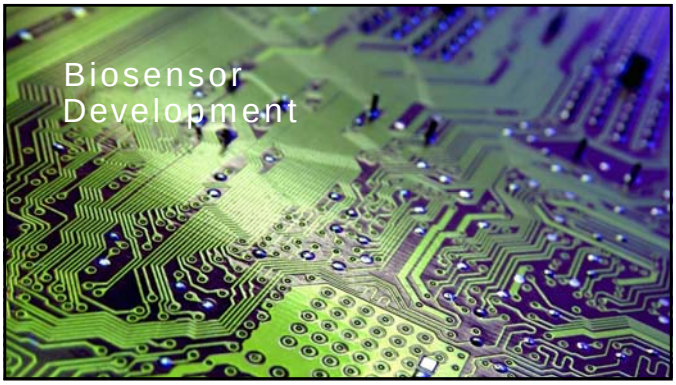
- Perform air dispersion modeling using MATLAB/ AERMOD

(American Meteorological Society/ Environmental Protection Agency Regulatory Model)









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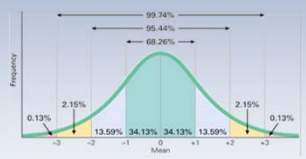
## Challenges for Odor Detection

- 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



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## State of the Art

Nasal Ranger

Olfactometry



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## 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



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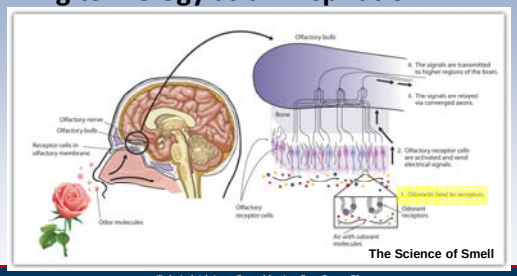
## Turning to Biology as an Inspiration



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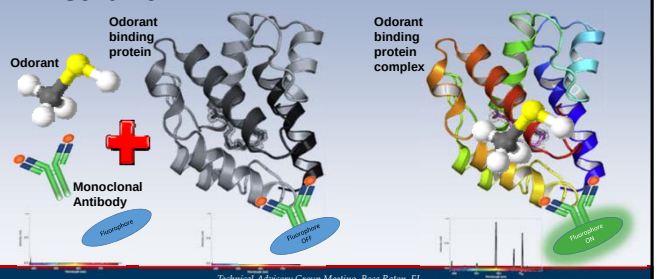
## Mechanism



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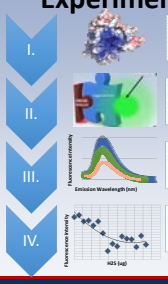
## Experimental Approach




- Synthesize hOBPIIa using *E. coli* expression vector (yield = 1.7µg/µL)
- Apply fluorescent tag (1-AMA) to the protein
- Perform binding experiments with odorants and mixtures
- Determine spectrofluorometry-based concentration-dependence

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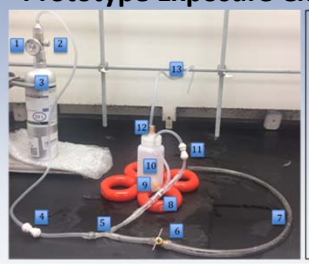
## Prototype Exposure Chamber



KEY
1 Regulator
2 Flow adjustment knob
3 29 L $H_2S$ tank
4 Coupling
5 Y-connector
6 Ball valve
7 Outlet tubing
8 Flow meter
9 One-way check valve
10 Reaction chamber
11 Coupling
12 One-way check valve
13 Effluent line



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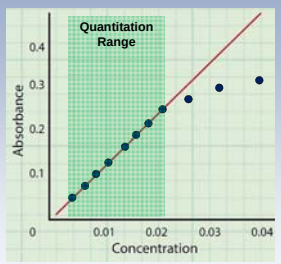
## Previous Work

- Created prototype biosensor
  - hOBPIIA + 1-AMA tag complex
- Exposed biosensor to $H_2S$ for various times
- Measured intensity of the spectroscopic signal to determine concentration relationship
- Varied concentration to determine detection & quantitation range



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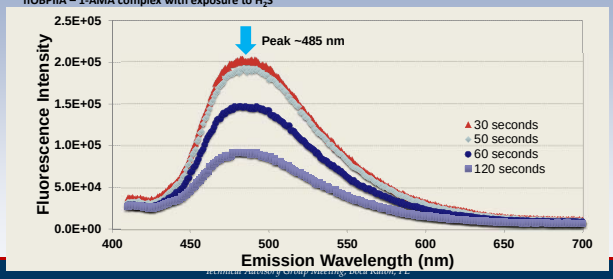
## Spectrofluorometry Emission

hOBPIIA – 1-AMA complex with exposure to $H_2S$



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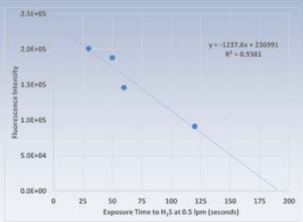
## Saturation Limit

- Model predicts complete saturation at 191 seconds for these conditions:
  - 100 mL of 50 mM $K_3PO_4$-KOH buffered to pH 7.5
  - 1.0 µM hOBPIIA
  - 1.0 µM 1-AMA
  - 25 ppm +/- 5% $H_2S$ (balanced with $N_2$)



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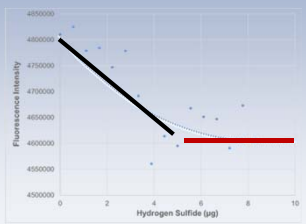
## Max Detection Limit @ 120 seconds

- Signal seems saturated from 5 – 10 µg $H_2S$
- Under these conditions, the maximum quantitation limit appears to be ~4-5 µg $H_2S$



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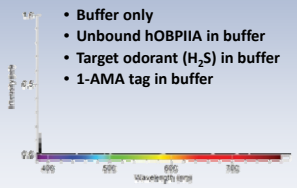
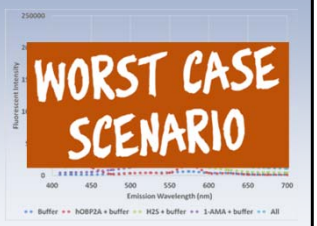
## Competitive Spectrofluorometry

- Checked for interference
  - Buffer only
  - Unbound hOBPIIA in buffer
  - Target odorant ($H_2S$) in buffer
  - 1-AMA tag in buffer





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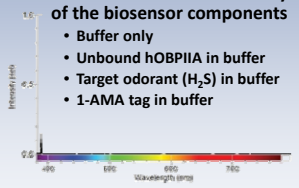
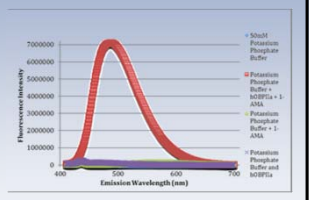
## Competitive Spectrofluorometry

- No emission detected for any of the biosensor components
  - Buffer only
  - Unbound hOBPIIA in buffer
  - Target odorant ($H_2S$) in buffer
  - 1-AMA tag in buffer






Interference max@485 nm <2%



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## Conclusions & Recommendations

- hOBPIIa was used for the first time to detect $H_2S$ 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 $H_2S$ 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 $H_2S$, the next step is to experiment with other odorants, gas mixtures and field samples common to MSW facilities



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## Upcoming Work

- Teaming up with Dr. Binninger (FAU-Biology)
- Testing the biosensor configuration
  - Fluorophore tag (1-AMA)
  - Monoclonal antibody
  - Positive vs. inverse response (bound v. 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

Hinkley Center for Solid and Hazardous Waste Management

EREF Environmental Research & Education Foundation



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## Goal



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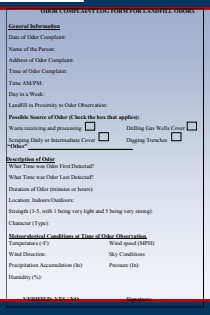
## Still Need Comments

- 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



ODOR COMPLAINT LOG FORM FOR LANDFILL ODORS

**General Information**

Date of Odor Complaint:

Name of the Person:

Address of Odor Complaint:

Time of Odor Complaint:

Time AM/PM:

Day in a Week:

Landfill in Proximity to Odor Observation:

**Possible Source of Odor (Check the box that applies):**

Waste receiving and processing ☐ Drilling Gas Wells Cover ☐

Scraping Daily or Intermediate Cover ☐ Digging Trenches ☐

**"Other"**

**Description of Odor**

What Time was Odor First Detected?

What Time was Odor Last Detected?

Duration of Odor (minutes or hours):

Location: Indoors/Outdoors:

Strength (1-5, with 1 being very light and 5 being very strong):

Character (Type):

**Meteorological Conditions at Time of Odor Observation**

Temperature (°F): Wind speed (MPH):

Wind Direction: Sky Conditions:

Precipitation Accumulation (In): Pressure (In):

Humidity (%):

VERIFIED: YES / NO Signature:



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## 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

| WS | WD | DP | P | ASC | dP |
|---|---|---|---|---|---|
| 5 mph | crosswind | 72°F | 1.5 mm/hr | D | -20 mbar? |
| | | | | | |
| <3 | Directly downwind | >75°F | >15 | F | |
| 4 – 7 | Slightly downwind | 65 – 75 | 7.5 – 15 | E | |
| 8 – 12 | Crosswind | 60 – 65 | 2.5 –7.5 | D | |
| 13 – 18 | Slightly upwind | 50 – 60 | 0.5 –2.5 | B-C | |
| >18 | Directly upwind | <50 | <0.5 | A | |

Critical
Severe
Substantial
Moderate
Low

Florida Atlantic University
College of Engineering & Computer Science

# "Investigation of Leachate Management Solutions at the Solid Waste Authority of Palm Beach County"

Daniel E. Meeroff, Bishow Nath Shaha
Florida Atlantic University
Department of Civil, Environmental & Geomatics Engineering

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## Background




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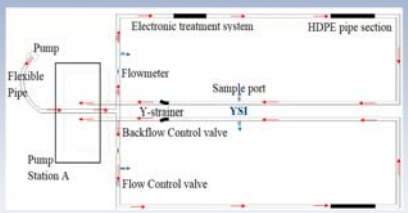
## Background




Pipe Network (40'x20')



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## Agenda

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



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### Task 1. Impacts of Flow Regime on Geochemical Rocking

| Sample ID | pH (field) | Field Cond. (mS/cm) | TDS (g/L) | Alk. (mg/L $CaCO_3$) | Ca (mg/L $CaCO_3$) | Field TDS (g/L) | Temp. (°C) | LSI | RI |
|---|---|---|---|---|---|---|---|---|---|
| MH 6 | 7.26 | 39.29 | 18.90 | 4,820 | 1,550 | 22.19 | 33.11 | 2.0 | 3.2 |
| MH 10 | 7.15 | 36.10 | 18.30 | 5,200 | 2,600 | 20.13 | 33.45 | 2.2 | 2.8 |
| PS/B | 7.23 | 30.80 | 15.30 | 4,810 | 3,280 | 18.85 | 32.62 | 2.3 | 2.6 |
| MH 12 | 7.26 | 26.98 | 9.50 | 3,740 | 1,420 | 14.76 | 32.90 | 1.9 | 3.5 |
| MH 14 | 7.26 | 21.91 | 9.70 | 2,840 | 1,250 | 12.10 | 32.06 | 1.7 | 3.9 |
| DIW | 7.40 | 1.12 | 0.60 | 970 | 470 | 0.68 | 28.70 | 1.3 | 4.8 |
| Deep well | 6.98 | 11.68 | 6.20 | 1,190 | 1,110 | 6.53 | 33.74 | 1.1 | 4.8 |
| NEFCO | 5.79 | 7.42 | 1.97 | 500 | 530 | 4.04 | 35.11 | -0.6 | 7.0 |

Average water quality parameters from 5 sampling events



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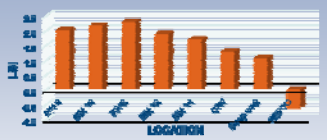
### Task 1. Impacts of Flow Regime on Geochemical Rocking




- 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

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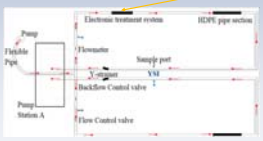
### Task 2. Impacts of Biological Activity as a Clogging Trigger Mechanism

- UV disinfection unit has been recommended and purchased





10 GPM flow
22"x4" chamber size



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### Task 2. Impacts of Biological Activity as a Clogging Trigger Mechanism

- Lab test:

| Microorganism | Required Fluence (mJ/cm²) 1 log red't | 2 log red't | 4 log red't |
|---|---|---|---|
| Bacteria | | | |
| *E. coli* | 5 | 9 | 18 |
| *E. coli* O157:H | 5 | 9 | 18 |
| *Salmonella typhia* | 8 | 12 | 51 |
| *Clostridium perfringense* | 45 | 95 | 6 |
| *Bacillus subtilles* | 56 | 111 | 222 |
| *Streptococcus faecalise* | 9 | 16 | 30 |
| *Campylobacter jejunii* | 3 | 7 | 14 |
| *Legionella pneumophilial* | 8 | 15 | 30 |
| *Shigel dysenteriaeil* | 3 | 5 | 11 |
| *vibrio cholerael* | 2 | 4 | 9 |

| Spectrum | Fluence (mJ/s.cm²) at the well surface |
|---|---|
| UV-A | 126 |
| UV-B | 129 |
| UV-C | 122 |
| UV-254 | 26 |



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### Task 2. Impacts of Biological Activity as a Clogging Trigger Mechanism

- Lab test:

| Distance from the well surface, cm | Fluence (mJ/cm².s) | |
|---|---|---|
| | UV-C | UV-254 |
| 0 | 122 | 26 |
| 3.55 | 9.7 | 2.1 |
| 7.65 | 2.1 | 0.4 |
| 12.5 | 0.8 | 0.2 |



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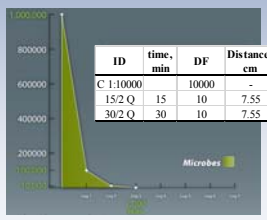
### Task 2. Impacts of Biological Activity as a Clogging Trigger Mechanism

- Lab test:




| ID | time, min | DF | Distance, cm | count (total) | CFU@35C/48h |
|---|---|---|---|---|---|
| C 1:10000 | | 10000 | - | 88 | 8,800,000 |
| 15/2 Q | 15 | 10 | 7.55 | 113 | 11,300 |
| 30/2 Q | 30 | 10 | 7.55 | 20 | 2,000 |

- ≤ 3-log reduction



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### Task 3. Impacts of pH adjustment for Enhanced Precipitate Control

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

Capacity: up to 170 GPD

Stenner 170LSA15TAA double head adjustable mechanical peristaltic pump, 8.5 - 170 gpd, 115 VAC



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### Task 3 Lab Experiments with Carbon Dioxide Gas - Methodology

Laboratory setup

Materials:

1. Calibration gas ($N_2$)
2. Calibration gas (0.01-49.99% $CO_2$)
3. 2L transparent plastic bottle (2)
4. Regulator (2) (1 liter per minute constant flow)
5. Gas releasing valve (2)
6. Sampling port (2)
7. At least 4L of leachate
8. Bubbling stone (2)

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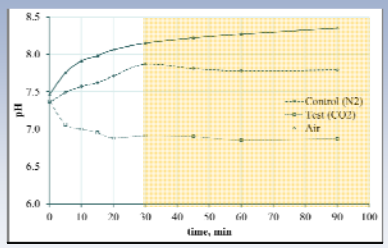
### Task 3 Lab Experiments with Carbon Dioxide Gas – Effect on pH




pH changes over time



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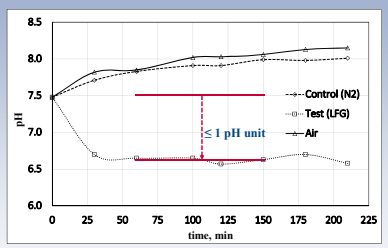
### Task 3 Lab Experiments with LFG– Effect on pH




pH changes over time



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### Task 3 Lab Experiments with Carbon Dioxide Gas – Effect on Saturation Indices

| Time, min | pH | TDS field, g/L | Alk, mg/L as $CaCO_3$ | Ca, mg/L as $CaCO_3$ | Temp., °C | pHs | LSI | RI |
|---|---|---|---|---|---|---|---|---|
| **Control ($N_2$)** | | | | | | | | |
| 0 | 7.35 | 6.86 | 1,230 | 1,900 | 18.37 | 5.9 | 1.5 | 4.4 |
| 30 | 7.87 | 6.81 | 1,300 | 1,700 | 21.27 | 5.9 | 2.0 | 3.9 |
| 60 | 7.78 | 6.78 | 1,270 | 1,750 | 21.76 | 5.9 | 1.9 | 3.9 |
| 90 | 7.79 | 6.66 | 1,280 | 1,750 | 22.36 | 5.8 | 1.9 | 3.9 |
| **Test ($CO_2$)** | | | | | | | | |
| 0 | 7.37 | 6.85 | 1,270 | 1,750 | 18.5 | 5.9 | 1.5 | 4.4 |
| 30 | 6.91 | 6.81 | 1,330 | 1,900 | 21.24 | 5.8 | 1.1 | 4.7 |
| 60 | 6.85 | 6.87 | 1,280 | 1,800 | 21.58 | 5.8 | 1.0 | 4.8 |
| 90 | 6.87 | 6.9 | 1,280 | 1,800 | 22.2 | 5.8 | 1.0 | 4.8 |
| **Air** | | | | | | | | |
| 0 | 7.46 | 6.94 | 1,600 | 1,350 | 15.82 | 6.0 | 1.5 | 4.5 |
| 30 | 8.15 | 6.77 | 1,400 | 1,650 | 19.43 | 5.9 | 2.3 | 3.6 |
| 60 | 8.27 | 6.71 | 1,150 | 1,600 | 20.61 | 6.0 | 2.3 | 3.6 |
| 90 | 8.35 | 6.67 | 1,150 | 1,600 | 21.41 | 5.9 | 2.4 | 3.5 |

- Increase in pH results higher LSI
  - $N_2$, and Air increase LSI
  - $CO_2$ decreases LSI



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### Task 3 Lab Experiments with Carbon Dioxide Gas – Effect on Saturation Indices

| Time, min | pH | TDS (g/L) | Alk, (mg/L Ca(CO3) | Ca, (mg/L Ca(CO3) | Temp., °C | pHs | LSI | RI |
|---|---|---|---|---|---|---|---|---|
| **Control ($N_2$)** | | | | | | | | |
| 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 |

- Increase in pH results higher LSI
  - LFG decreases LSI



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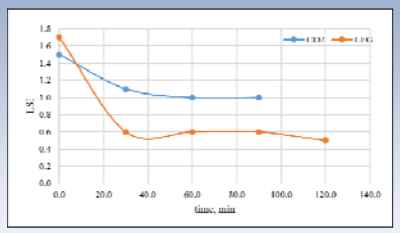
### Task 3 Lab Experiment result summary




- Increase in pH results higher LSI
  - LFG decreases LSI



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### Task 4. Impacts to the Deep Injection Well – Based on March 2017 flows

| Water Source | March, 2017 | pH | TDS | Alk | Ca | Cond | Temp | pHs | LSI | RI |
|---|---|---|---|---|---|---|---|---|---|---|
| P/S A | 2,107,739 | 7.1 | 17,400 | 1,574 | 3,175 | 23.3 | 29.0 | 5.5 | 1.6 | 3.9 |
| P/S B | 1,853,950 | 7.2 | 15,300 | 4,810 | 3,280 | 30.8 | 32.6 | 4.9 | 2.3 | 2.6 |
| P/S C | 1,527,000 | 7.6 | 3,561 | 1,750 | 775 | 7.4 | 31.1 | 5.9 | 1.8 | 4.1 |
| P/S D | 1,372,000 | 7.0 | 3,608 | 2,100 | 600 | 8.5 | 30.0 | 5.9 | 1.1 | 4.8 |
| DYER | 1,668,000 | 7.1 | 2,303 | 1,618 | 565 | 3.6 | 28.4 | 6.0 | 1.1 | 4.8 |
| CISW | 264,291 | 7.4 | 600 | 970 | 470 | 1.1 | 28.7 | 6.1 | 1.3 | 4.8 |
| ISW | 3,119,050 | 7.4 | 600 | 970 | 470 | 1.1 | 28.7 | 6.1 | 1.3 | 4.8 |
| Plant water | 7,845,300 | 7.2 | 3,644 | 155 | 1,364 | 4.6 | 32.5 | 6.7 | 0.9 | 5.8 |
| NEFCO | 7,372,000 | 5.8 | 1,970 | 500 | 530 | 7.4 | 35.1 | 6.7 | -0.6 | 7.0 |
| AVG | 27,129,330 | 7.3 | 4,586 | 1,057 | 1,177 | 8.4 | 32.0 | 6.1 | 0.9 | 5.2 |
| DEEPWELL | | 7.0 | 6,200 | 1,190 | 1,110 | 11.7 | 33.7 | 5.9 | 1.1 | 4.8 |

Estimated LSI using mass balance

Actual LSI

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## 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)



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## Future Work

- Task 2. Impacts of Biological Activity as a Clogging Trigger Mechanism
  - Lab experiments with a small scale UV disinfection unit
    - HPC total plate counts v. UV exposure time with P/S B
    - Microscopic morphological analysis (*Desulfo vibrio* is comma shaped)
  - Perform a leachate bleed test using side by side pipe network
    - Microbiology and mineral testing



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## Future Work

- 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 ($CO_2$) addition
    - Water quality and mineral testing
    - Goal is to create guidance for acid addition



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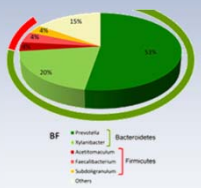
## Future Work

- Task 4. Impacts to the Deep Injection Well
  - FAU will monitor the flows and loadings with data beyond March 2017
  - FAU is working with AECOM/URS to determine biofilm microbiology and minerology
  - FAU will investigate and recommend options for trapping leachate solids prior to disposal in the deep injection wells



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## Future Work

- 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



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**Thank you**

**Questions???**


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FAU
FLORIDA ATLANTIC UNIVERSITY
Daniel Meeroff, Ph.D.
Associate Chair & Professor
Director, Laboratories for Engineered Environmental Solutions
Civil, Environmental & Geomatics Engineering
777 Glades Rd., Bldg. 36, Rm. 206
Boca Raton, FL 33431
tel: 561.297.3099
email: dmeeroff@fau.edu
http://labees.civil.fau.edu