Landfill Leachate Management with Adsorbent-Enhanced Constructed Wetlands

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Tampa, FL

September 8, 2022

Outline

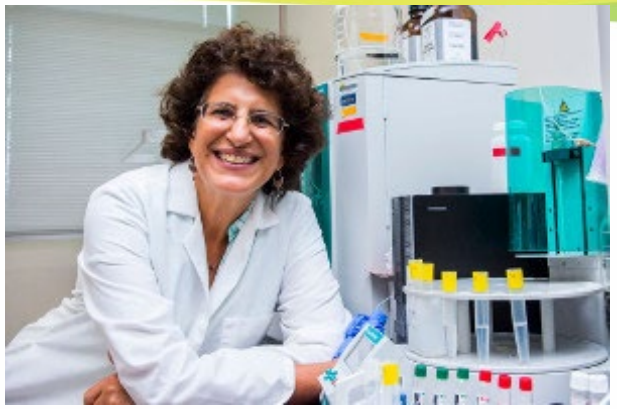
1. Introduction to Technical Awareness Group and Team Members
2. Overview of Phase II Research Plan
3. Practical Specific Benefits for End Users
4. Timeline and Milestones
5. Project Deliverables and Dissemination
6. Metrics to Date

TAG Members

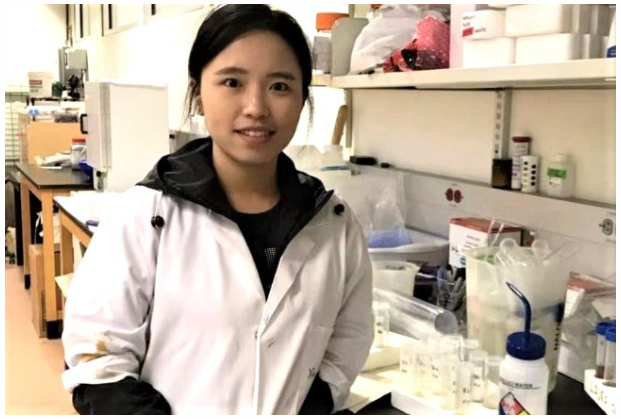
Name	Position/Affiliation
James S. Bays	Technology Fellow, Jacobs Engineering
Kimberly A. Byer	Solid Waste Management Division Director, Hillsborough Co.
Stephanie Bolyard	Research Engineer, NCDOT Research and Development Office
William J. Cooper	Prof. Emeritus, UC Irvine (Courtesy Prof. Env. Engineering UF)
Ashley Danely-Thomson	Assistant Professor, Florida Gulf Coast University
Viraj deSilva	Sr. Treatment Process Leader / Freese and Nichols, Inc.
Scott Knight	Wetland Solutions, Inc.
Ashley Evans	Market Area Engineer, Waste Management, Inc., Florida
James Flynt	Chief Engineer, Orange Co Utilities, Solid Waste Division
Melissa Madden-Mawhir	Senior Program Analyst, FDEP
Marcus Moore	Facilities Manager, Hillsborough County Water Resources Dept.
Luke Mulford	Senior Professional Engineer, Hillsborough County
Larry E. Ruiz	Landfill Operations Manager Hillsborough County

Team members

Mauricio Arias (Co-PI)



Sarina Ergas (Co-PI)



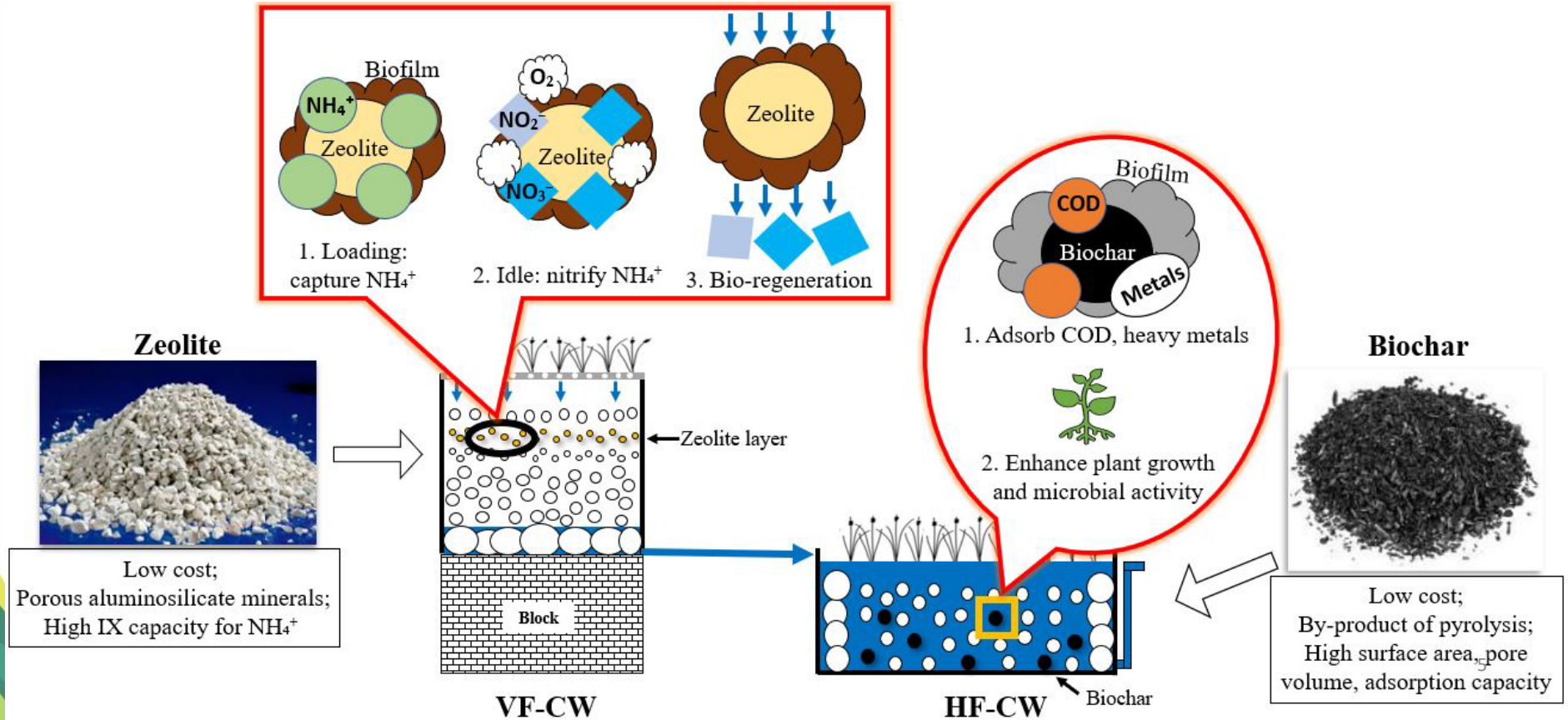
Xia Yang (PhD Student)

Nisa Ishfaqun
(MS Student)

Thanh “Misty” Lam, MS
(Alumna)

BACKGROUND

- Landfill leachate: High ammonia, color, recalcitrant organic matter and metal concentrations.
- Hybrid vertical/horizontal subsurface flow constructed wetlands: cost-effective for onsite leachate treatment.
- INNOVATIVE SCIENTIFIC CONTRIBUTION: Use of adsorbent media (zeolite and biochar) to enhance treatment performance



PHASE II RESEARCH PLAN

Research Questions

1. What are the effects of leachate strength and hydraulic loading on adsorbent enhanced bioreactor performance?

2. What is the cumulative effect of zeolite and biochar addition on ammonia and recalcitrant organic matter removal in VF-HF CWs?

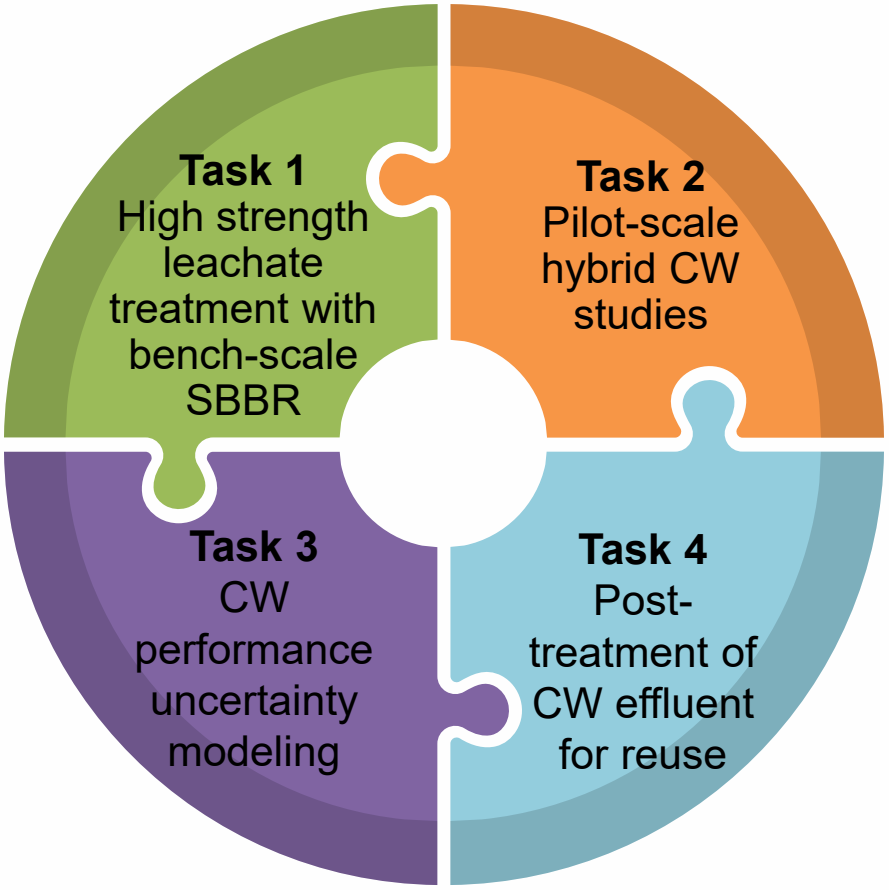
3. What are the effects of uncertainty in leachate quality, loading rates, and adsorbent addition on CW performance?

4. Does the addition of biochar promote wetland plant growth and transpiration?

5. Can adsorbent-amended VF-HF CWs provide a good pre-treatment method for UF-RO to produce reclaim water?

Task Overview

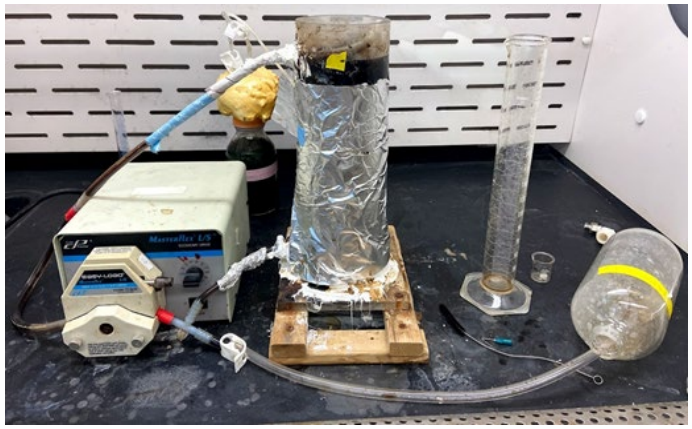
Project Goal: To optimize the design and operation of low-cost, low-complexity adsorbent-enhanced CWs for landfill leachate management.

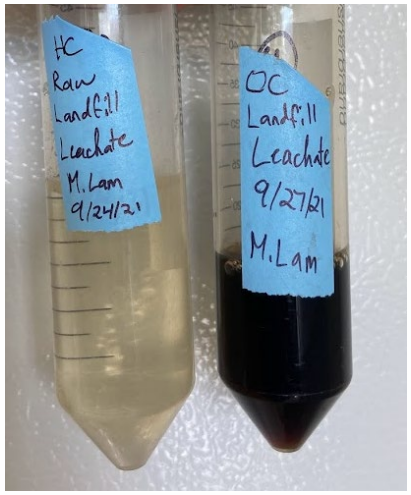


Task 1: High Strength Leachate Treatment with Bench-Scale SBBR

Objective: Investigate treatment of high-strength leachate collected from Florida landfills in bench-scale adsorbent amended SBBR.

Parameter	Hillsborough County SE	Orange County Cell 7B/8
NOx (mg/L)	80	BDL
TAN (mg/L)	375	1,550
sCOD (mg/L)	460	6,200
Elec. Cond. (mS/cm)	13.7	19.7
UV254 (A)	3.51	92.8
UV456 (A)	0.242	5.69





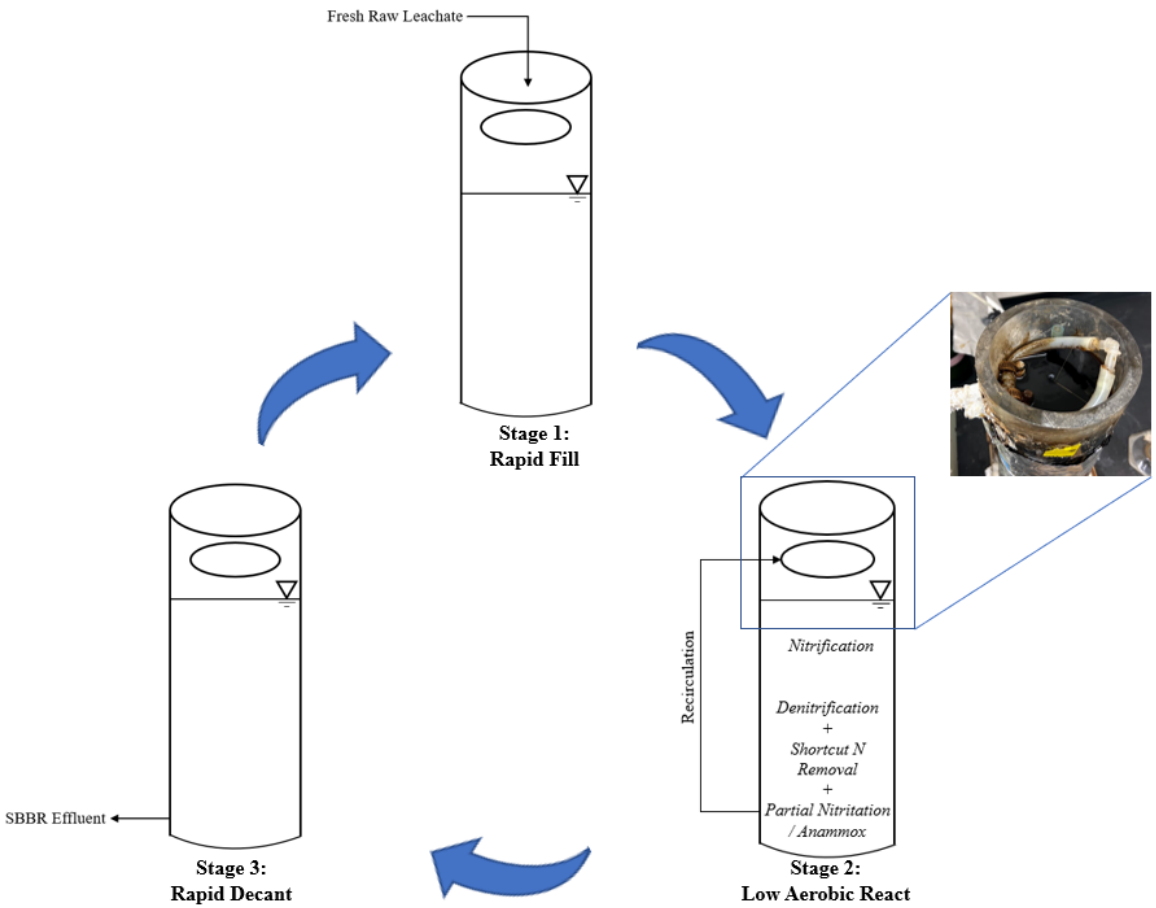
Task 1: Methods

SBBR Operation

HRT (days)	Fill/Decant Volume (mL)
21	100
14	130
10.5	180

Chemical Analysis

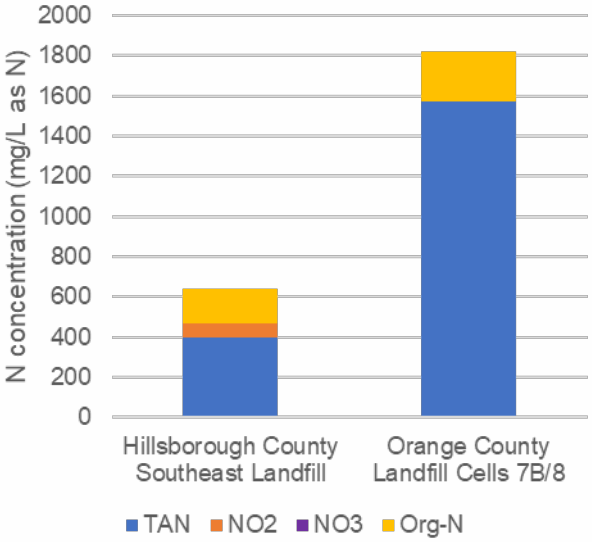
- Total Inorganic Nitrogen Species
- sCOD
- Color



Task 1: Results

Pollutant Removal Efficiencies Comparison to Our Phase I SBBR Study with Lower Strength Leachate

Nitrogen Species of Raw Landfill Leachate



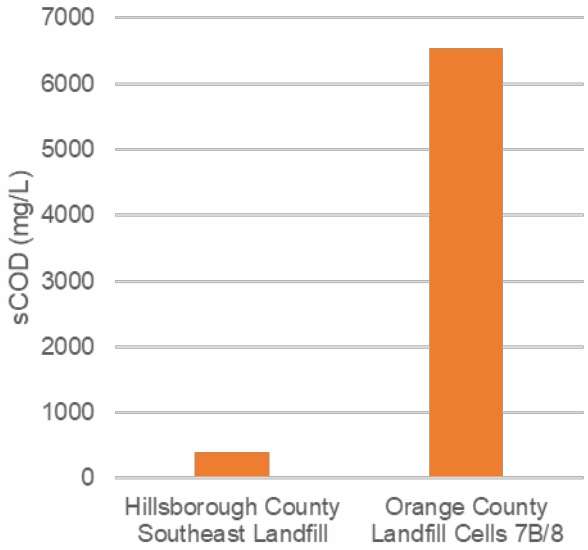
TIN Removal Efficiency and Rate Comparison

HRT (days)	TIN Removal Efficiency (%)	TIN Removal Rate (mg/L-day)
Hillsborough County Southeast Landfill Leachate		
14	99	33.2
9	57	29.8
9	99.7	52.1
Orange County Landfill Cells 7B/8 Leachate		
21	99.8	74.6
14	97.3	109
10.5	81.6	122

Task 1: Results

Pollutant Removal Efficiencies Comparison to Our Phase I SBBR Study with Lower Strength Leachate

sCOD Concentrations of Raw Landfill Leachate

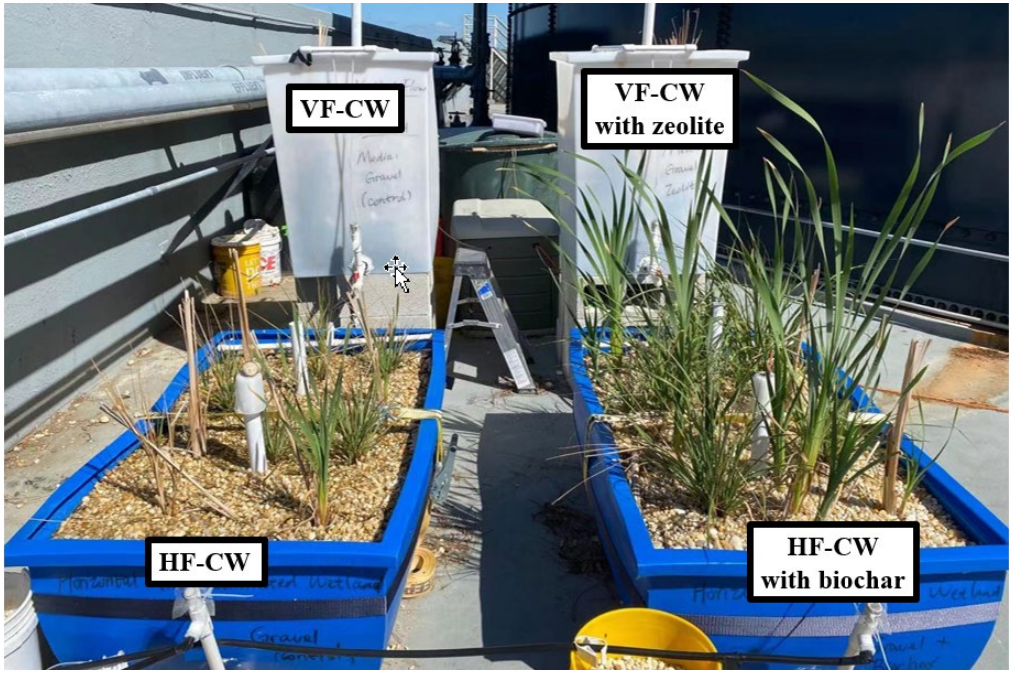


sCOD Removal Efficiency and Rate Comparison

HRT (days)	sCOD Removal Efficiency (%)	sCOD Removal Rate (mg/L-day)
Hillsborough County Southeast Landfill Leachate		
14	83.4	23.8
9	61.3	27.2
Orange County Landfill Cells 7B/8 Leachate		
21	48.7	151
14	46.5	217
10.5	35.9	223

Task 2: Pilot-Scale Hybrid CW Studies

Objective: Investigate long-term leachate quality and quantity performance of pilot-scale CWs operated at Hillsborough County's SE landfill under varying conditions.



Task 2: Methods

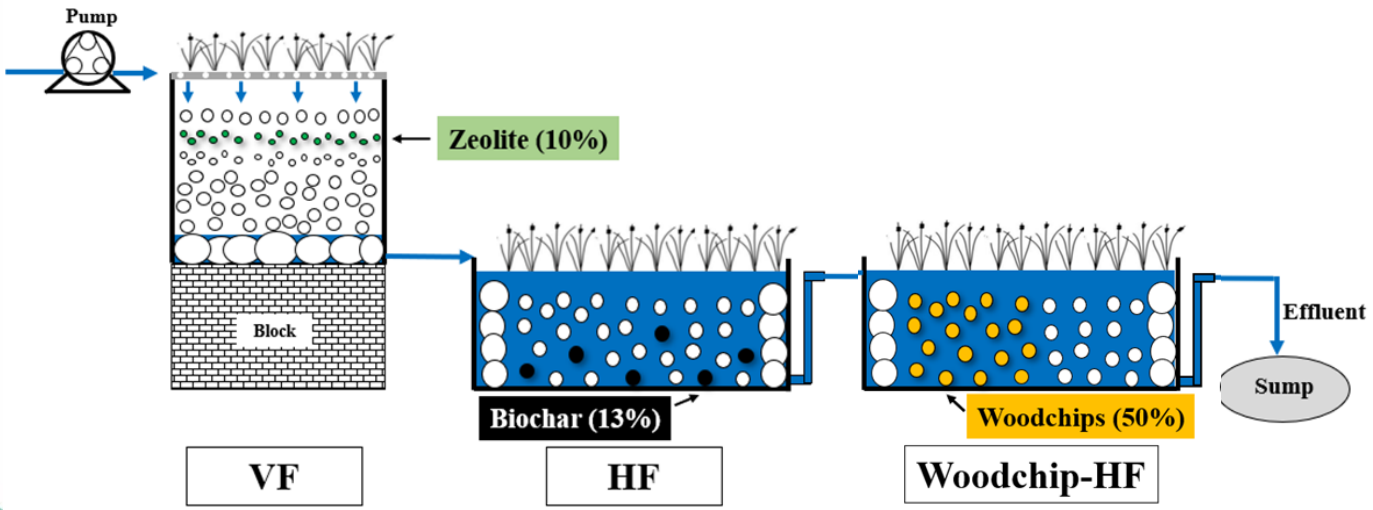
Operational conditions

	Flow Rate (L/d)	HLR (cm/d)	HRT (d)	#days
I	Acclimation			50
II	24	1.6	11	250
III	40	2.7	7	250
IV	60	4.0	4.5	190

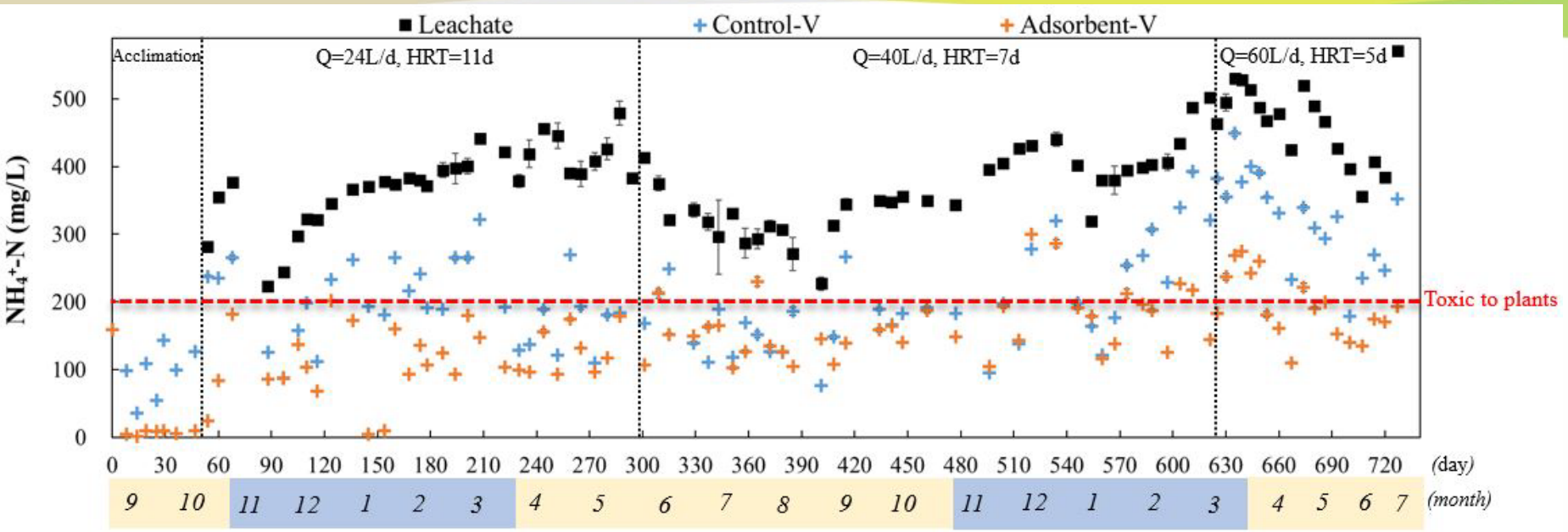
Day 540

Woodchip-CW

Gravel + Woodchips (1:1)



Task 2: Results: N species-VF CW



	Q 24L/d; HRT 11d	Q 40L/d; HRT 7d	Q 60L/d; HRT 4.5d
Control-V	43 ± 16.2	63 ± 19.9	86 ± 25.1
Adsorbent-V	62 ± 15.5	80 ± 22.6	163 ± 24.0
Mass loading rate (g/d)	9	15	28

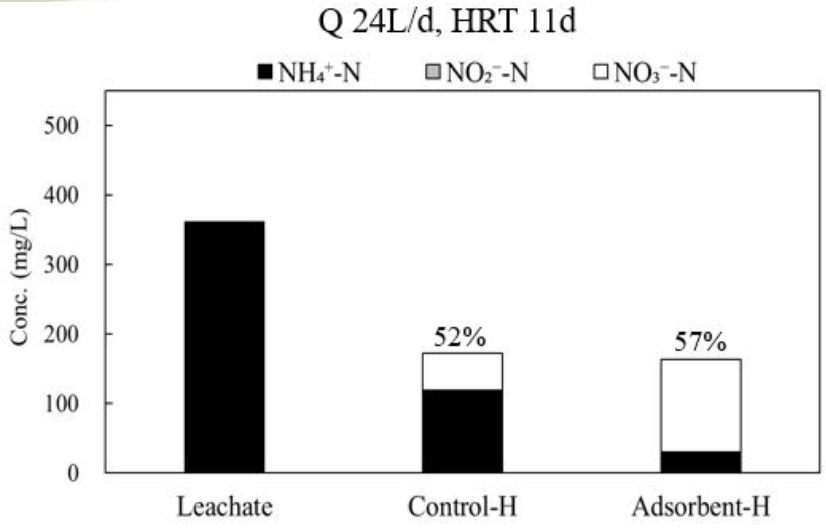
- Zeolite enhances nitrification;
- Correlation

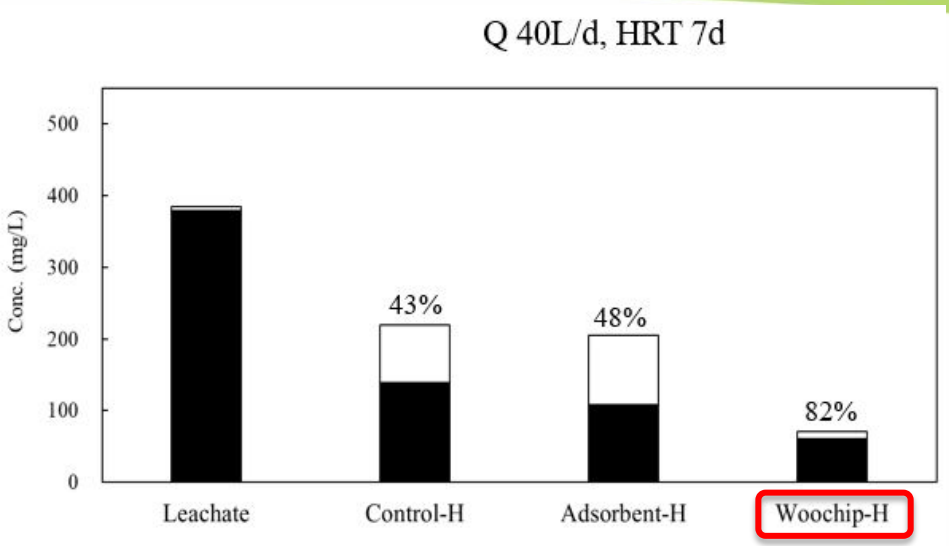
(nitrification vs. mass loading rate):

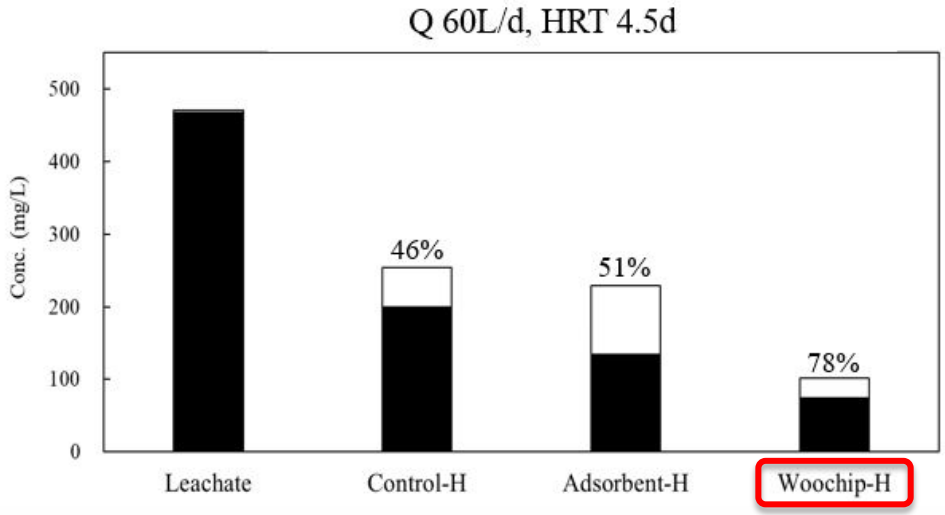
Control-V (+0.62)

Adsorbent-V (+0.92)

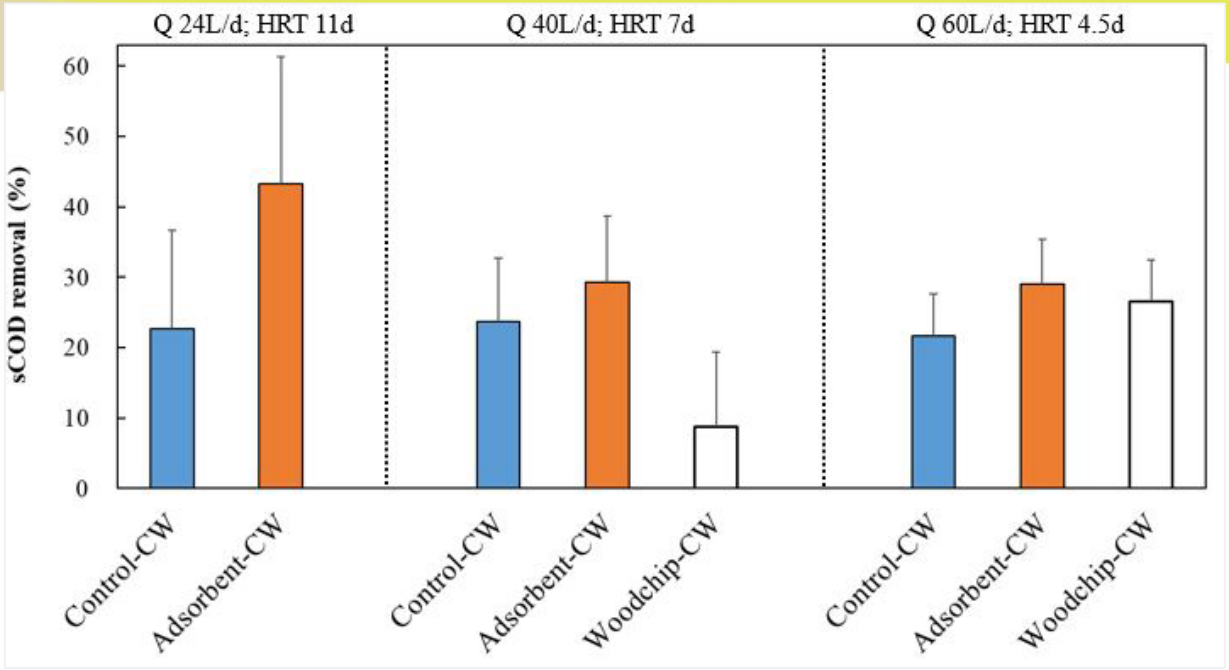
Task 2: Results-N Species-HF CW





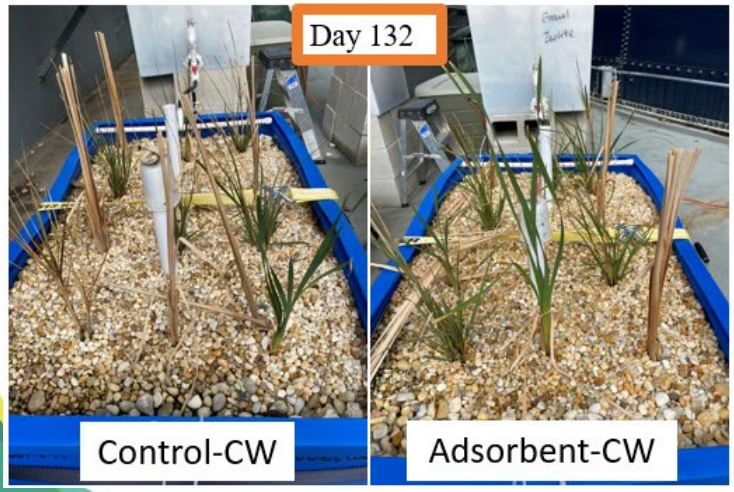


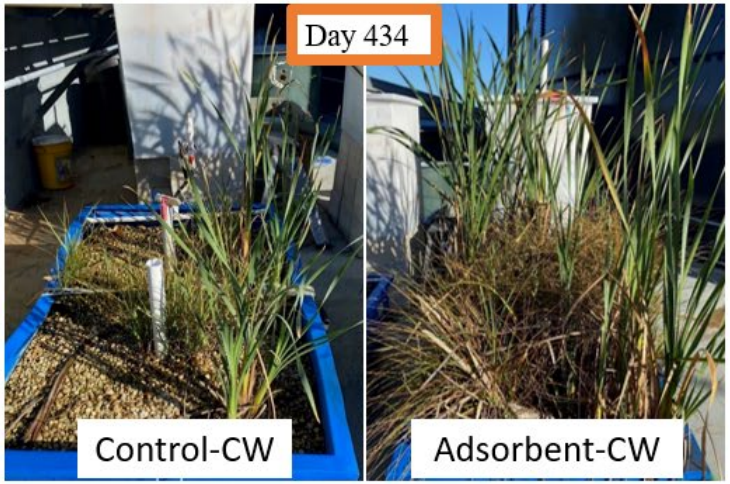
Task 2: Results-Organic Matter and Plants



Effluent concentration

	COD (mg/L)	BOD (mg/L)
Control	350	6
Adsorbent	330	2
Woodchip	420	7





Task 2: Next Steps

- Feeding frequency effect test
- Harvest plants (both roots and aboveground) for TN measurement
- Microbial community analysis

Task 3: CW Performance Uncertainty Modeling

Objective: To evaluate the effects of uncertainty on leachate quality/quantity and adsorbent composition on the performance of a pilot-scale CW system.

- Assess the effect of uncertainty in leachate quality, loading rates, and adsorbent addition on CW performance.

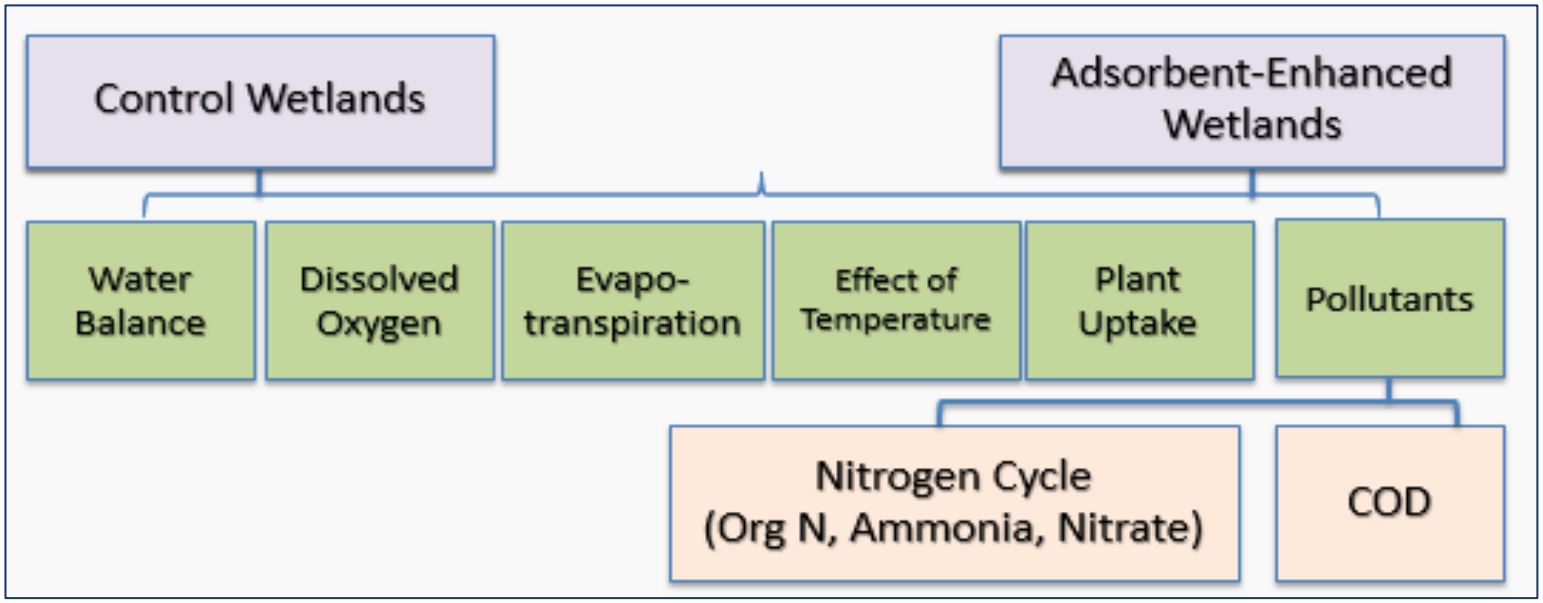
- Scaling up for a system capable of treating the average leachate discharge from the Hillsborough County's SE landfill (60,000-130,000 gal/day).

Douglas Road Landfill Leachate Treatment Wetland IN

(courtesy Jim Bays Jacobs Engineering)

Task 3: Methods

Overview of processes included:



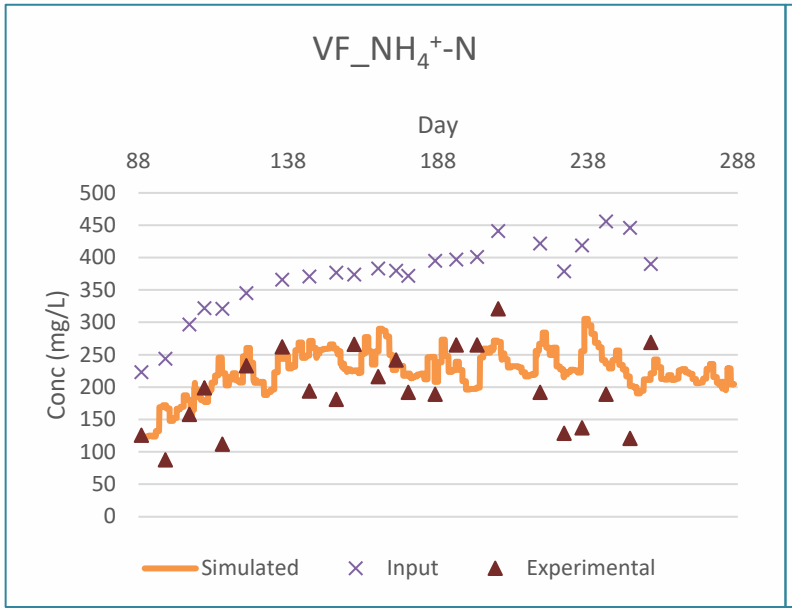
- Preliminary modeling and experiments carried out to characterize cells' hydraulics
- Simulations carried out at hourly time steps, for a total of 7 months
- Data from Task 2 used to parametrize the model

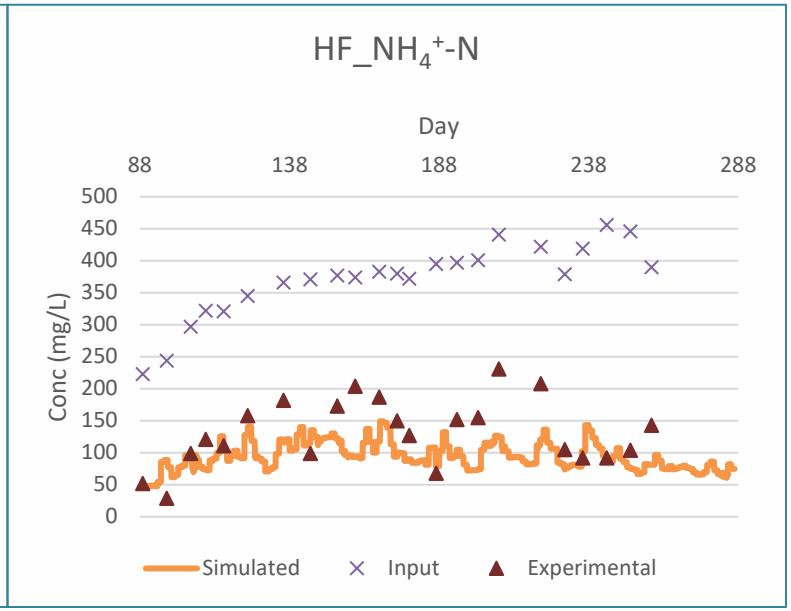
Task 3: Results

Control Wetlands

Take home messages related to NH_4^+-N :

- The model captures NH_4^+-N reduction trends in the VF-CW
- The model slightly overestimates NH_4^+-N reduction in the HF-CW



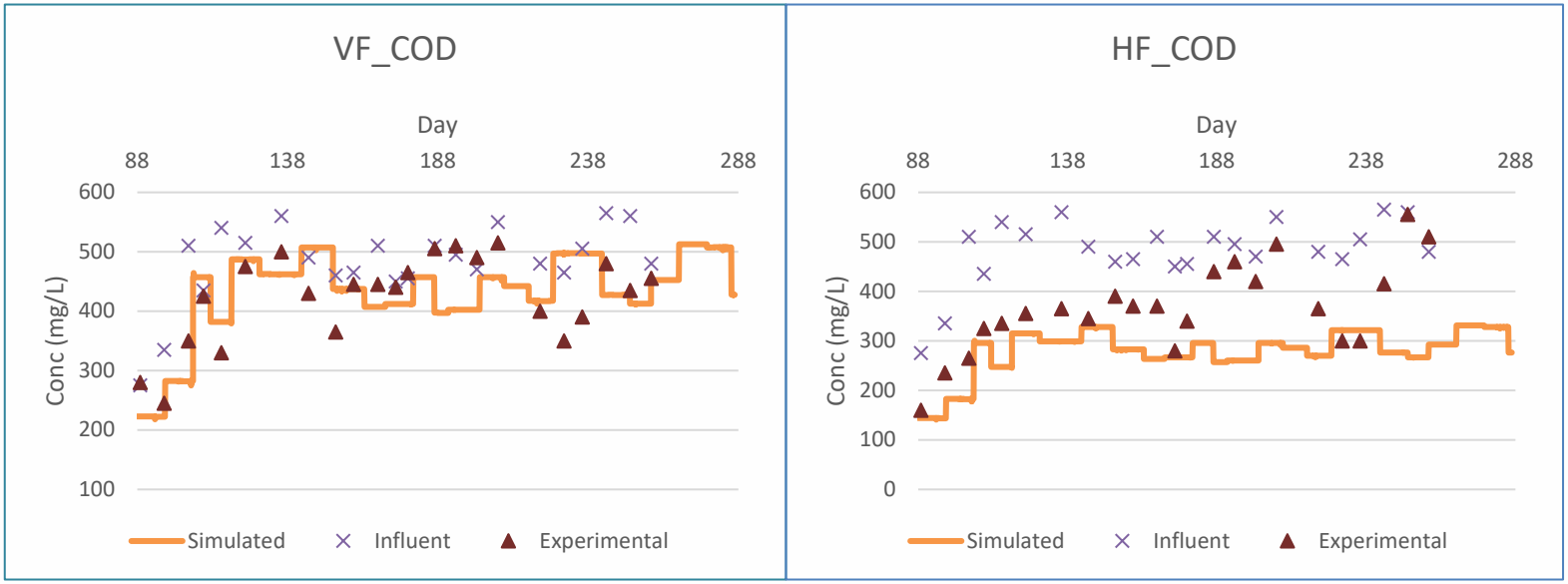


Task 3: Results

Control Wetlands

Take home messages related to COD:

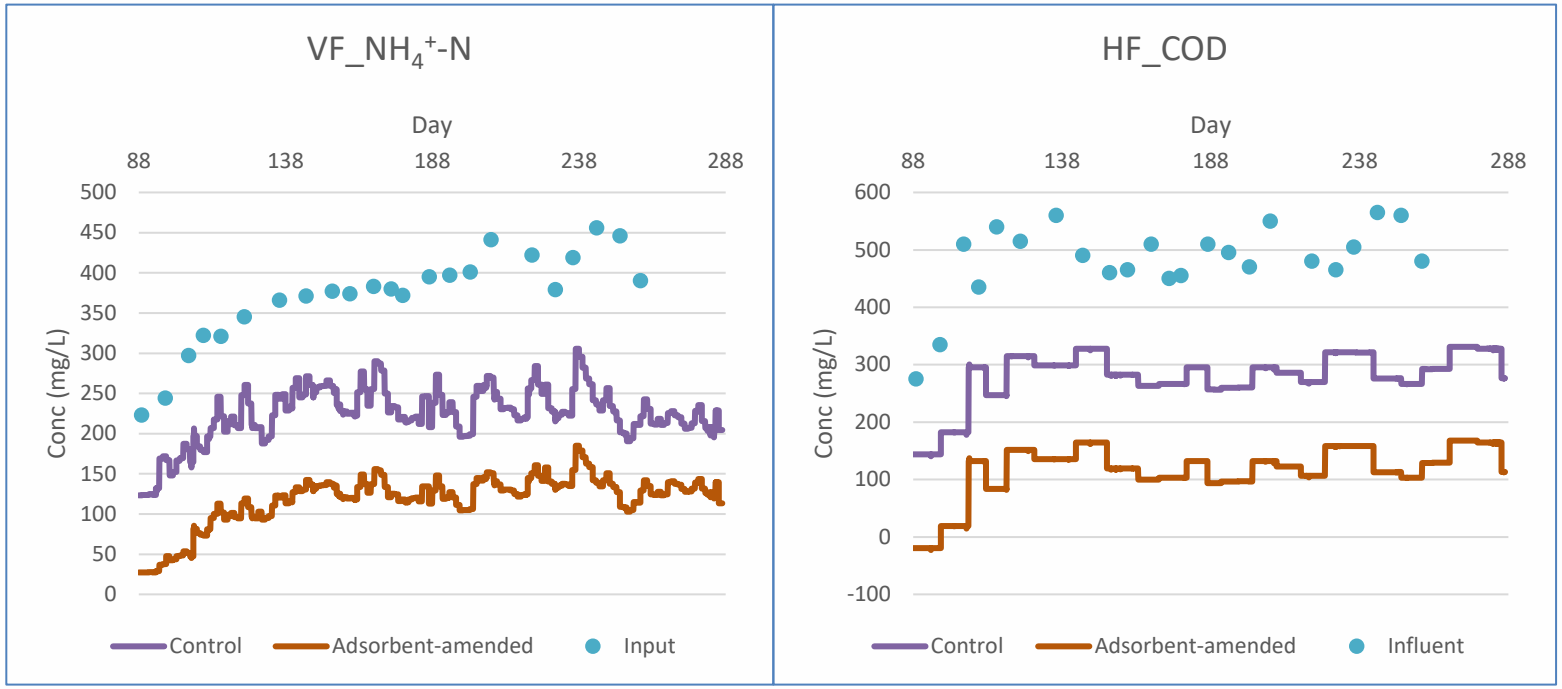
- The model captures COD reduction trends in the VF-CW
- The model overestimated COD reduction in the HF-CW



Task 3: Results

Control vs Adsorbent-Enhanced

The model predicts the effect of the amendments in COD and NH_4^+-N reduction

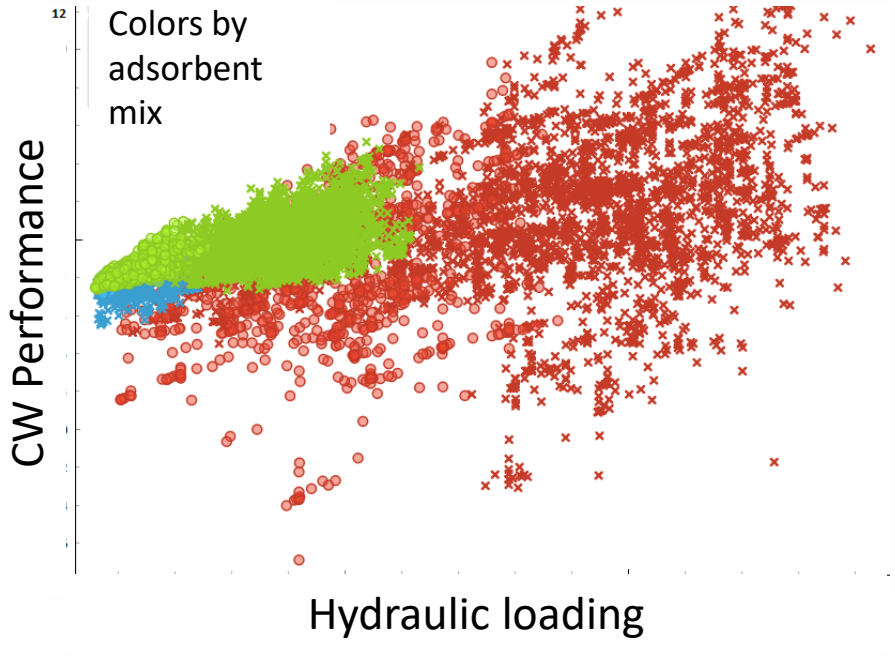


Task 3: Next Steps

- Complete model calibration
- Carry out uncertainty analysis
- Complete scale-up analysis for landfill average leachate discharge

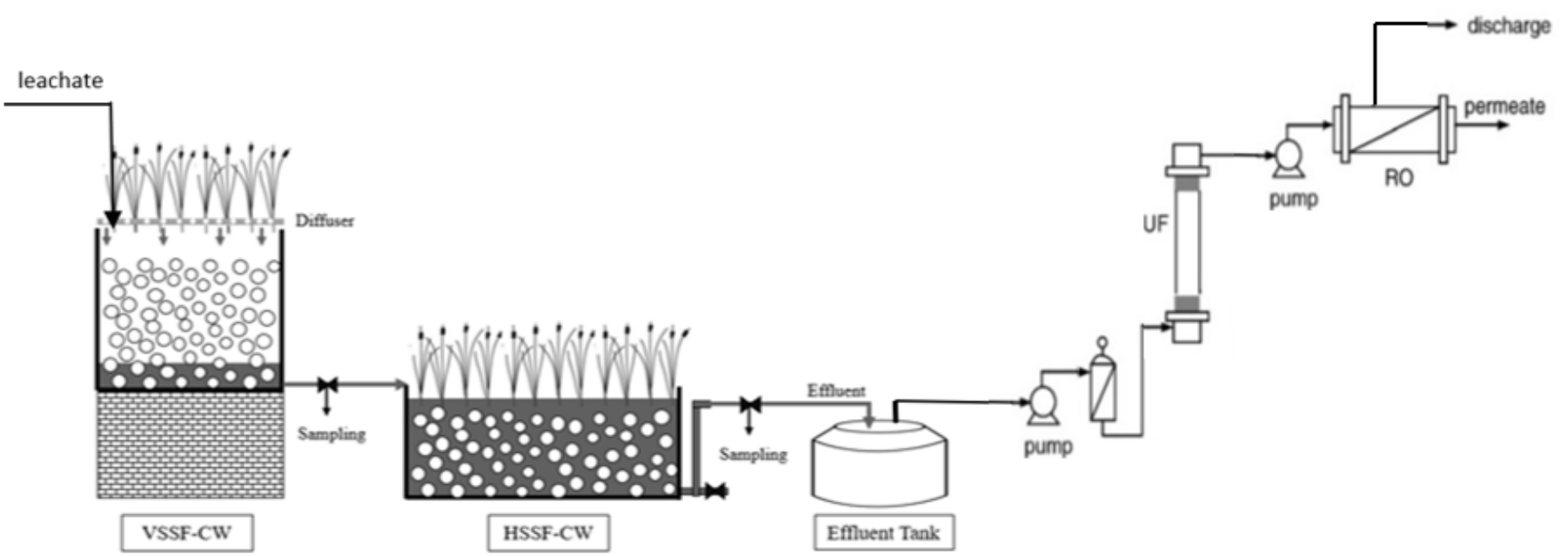
Uncertainty analysis example

(from Benjamin, Zhang, and Arias (2020)



Task 4: Post-treatment of CW Effluent for Reuse

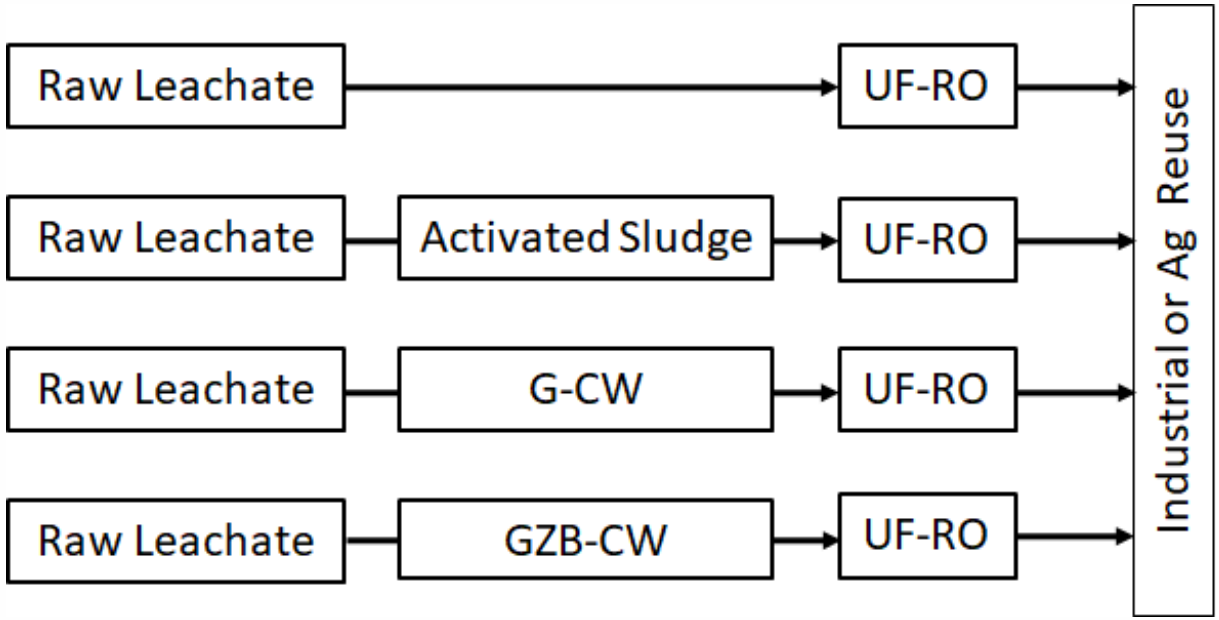
Objective: Evaluate the most technically and economically viable landfill leachate treatment and reuse strategy using Hillsborough County as a case study.



Proposed treatment train for reclaim water production from leachate.

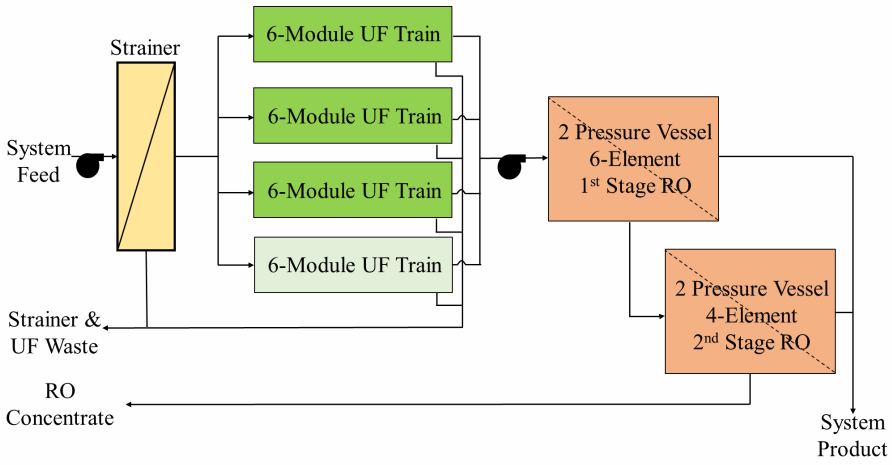
Task 4: Methods

- Effluent from CWs meets agricultural and industrial reuse standards, except for electrical conductivity.
- Design and simulate UF-RO system using WAVE Software

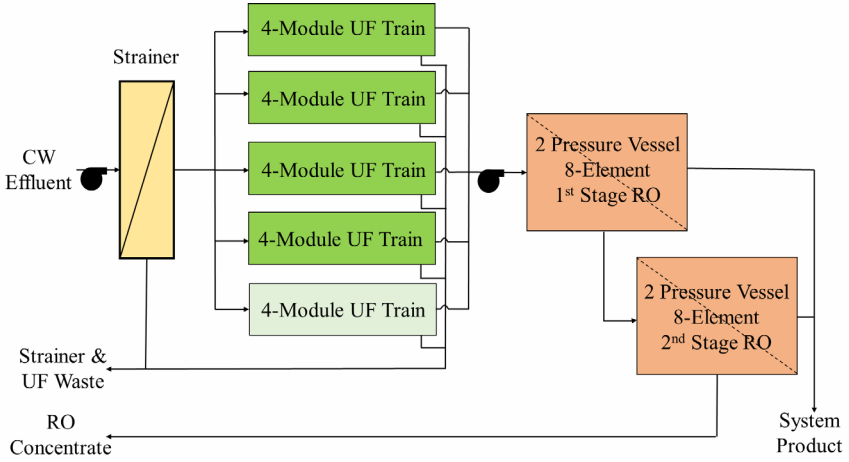


Task 4: Results Model Configurations and Product Flow Quantities

Common Design Configuration



CW Optimized Configuration



Water Recovery

UF-RO Feed	Permeate m^3/day	Concentrate m^3/day	Water Recovery %
Raw Leachate	306	451	42.1
AS Treated Leachate	307	450	42.2
Control-CW Optimized	380	377	52.2
Adsorbent-CW Optimized	416	341	57.2

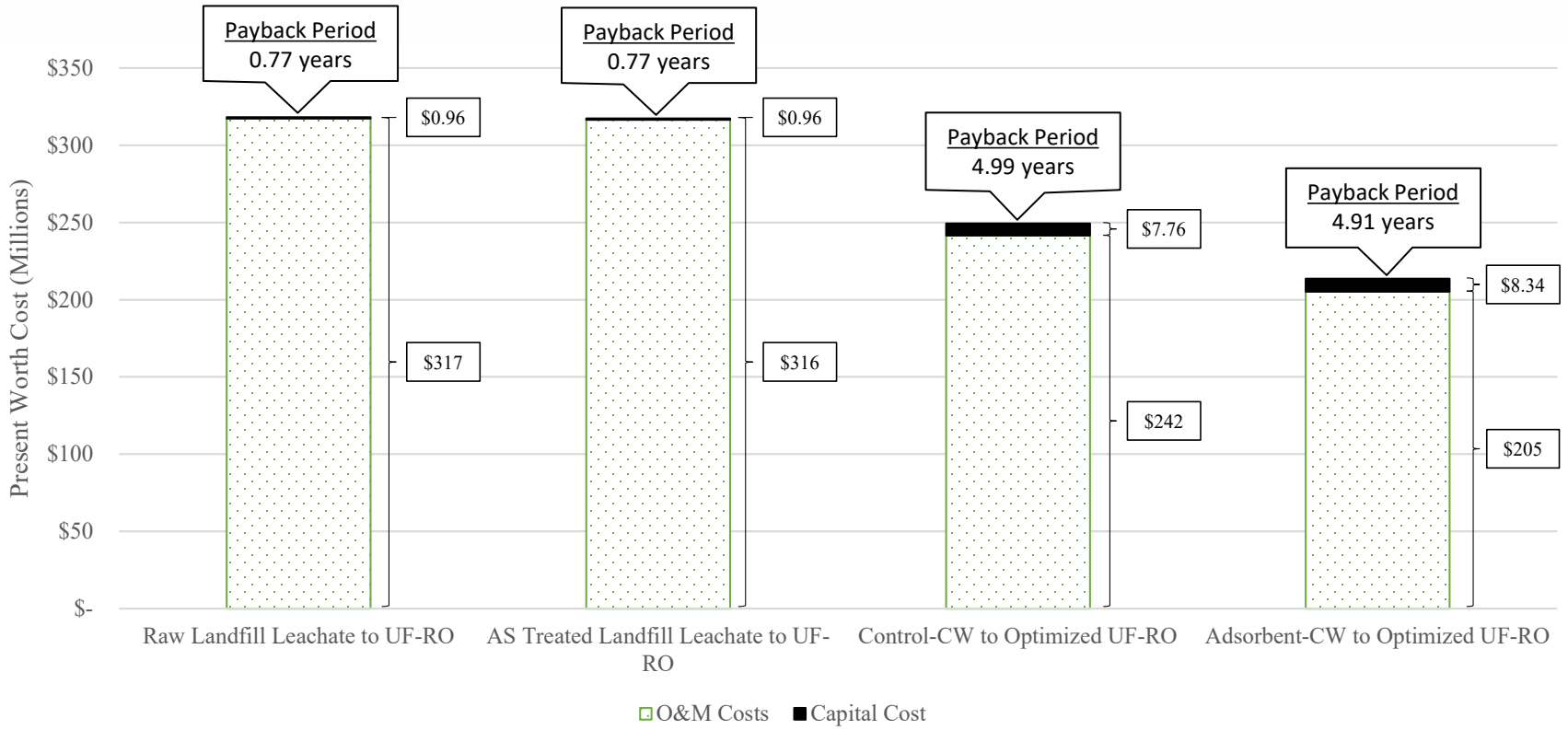
Task 4 Results: Equivalent Annual Cost Analysis

Design life = 20 years

Interest Rate = 5%

Economic analysis does not include:

- Activated sludge treatment O&M costs
- CW O&M costs
- On-site evaporator



Practical Specific Benefits For End Users

"Leachate management can be a significant component of the Long-Term care estimates based on the current models for leachate generation."

- Benefits of onsite landfill leachate management with CWs:
  - Low complexity, low capital and O&M costs.
  - Proven performance for TN, BOD_5, COD, TSS, Color removal.

- Addition of low cost natural adsorbents, zeolite and biochar, enhanced treatment performance of hybrid VF-HF CWs.

- It is economically feasible to reclaim landfill leachate for agricultural or industrial reuse using CW => UF => RO treatment.

Timeline and Milestones

	Task	Q1	Q2	Q3	Q4	Q5	Deliverable
1)	Bench-scale studies	✓	✓				Proof of concept, publications
2)	Pilot-scale studies	✓	✓	✓	✓	○	Long term performance data, publication
3)	Uncertainty modeling	✓	✓	✓	○	○	Uncertainty analysis, publication
4)	Post-treatment for reuse	✓	✓				Scale-up, economic & acceptability
	Education & outreach	✓	✓	✓	✓		Students, professionals, community
	TAG meetings	✓			✓		Slides, videos and photos in website
	Quarterly & final reports	✓	✓	✓		○	Reports for Hinkley and USF websites

Phase II Dissemination Metrics to date

Scientific publications:

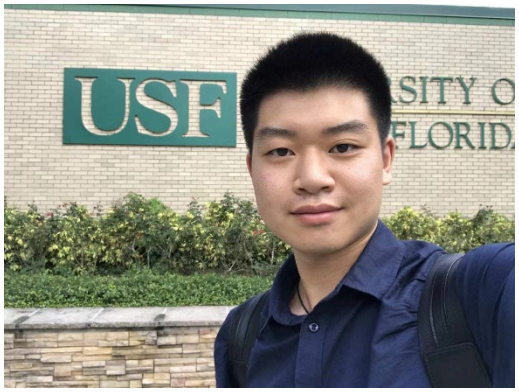
1. Gao, B., Yang, X., Dasi, E. A., Lam, T., Arias, M. E., & Ergas, S. J. (2022). Enhanced landfill leachate treatment in sequencing batch biofilm reactors (SBBRs) amended with zeolite and biochar. *Journal of Chemical Technology & Biotechnology*, *97*(3), 759-770.
2. Gao, Bisheng. *Enhanced Nitrogen, Organic Matter and Color Removal from Landfill Leachate by Biological Treatment Processes with Biochar and Zeolite*. University of South Florida, 2020.
3. Lam, Thanh Thieu. *Use of Biochar and Zeolite for Landfill Leachate Treatment: Experimental Studies and Reuse Potential Assessment*. Masters Thesis, University of South Florida, 2021.
4. Mulligan, Lillian. *Development of a Numerical Process Model for Adsorbent-amended Constructed Wetlands.* Masters Thesis, University of South Florida, 2021.
5. Lam, T. et al. Feasibility of Landfill Leachate Reuse through Adsorbent-Enhanced Constructed Wetlands and Ultrafiltration-Reverse Osmosis (Manuscript under review in *Desalination*)

Presenter(s)	Venue	Date
Xia Yang	American Ecological Engineering Society Annual Meeting, Baltimore	June 2022
Sarina Ergas	Association of Environmental Engineering & Science Professors, St. Louis	June 2022
Misty Lam	Florida Water Resources Conference, Daytona Beach	April 2022

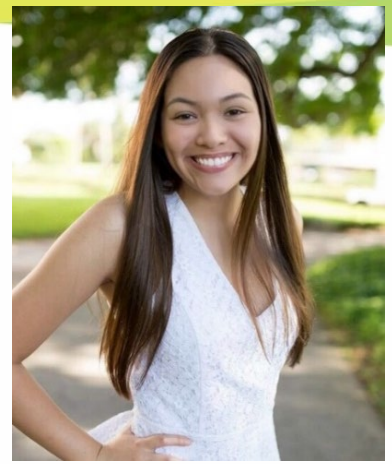
Metrics: Past Student Researchers

Erica Dasi, PhD

Xufeng Wei, MS

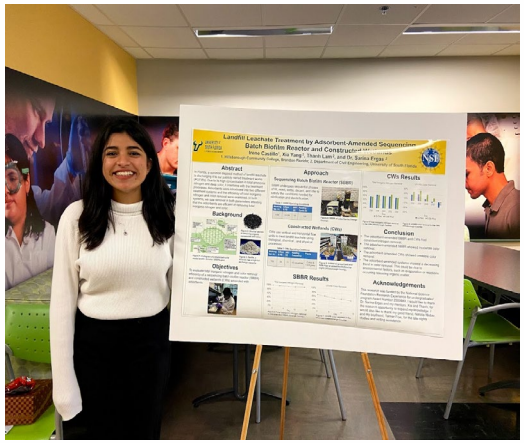


Bisheng Gao, MS



Lillian Mulligan, MS

Magdalena Shafee
(Undergrad)



Irene Castillo
(Community College)

Nicholas Truong
(Undergrad Student)

Thank You!

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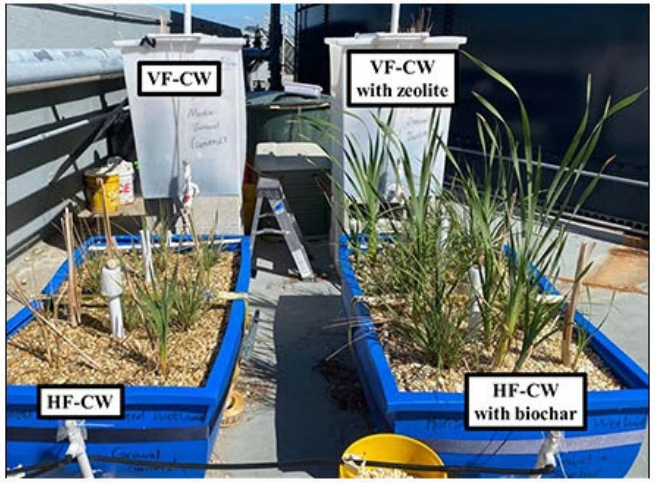
Project Title: Cost-Effective Hybrid Constructed Wetlands for Landfill Leachate Reclamation



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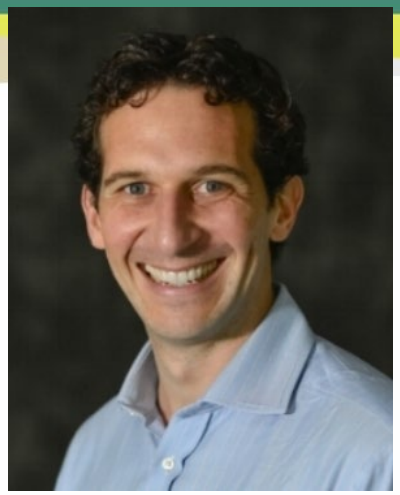
Hinkley Center
for Solid and Hazardous
Waste Management

Questions?



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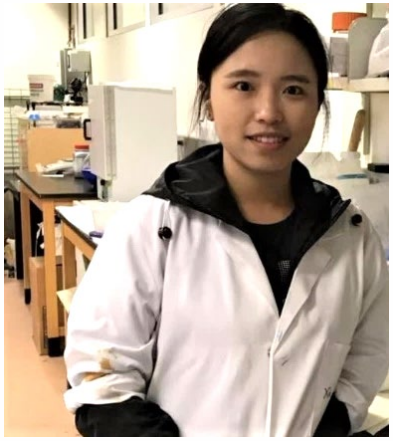

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Nisa Ishfaqun
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Task 3: Results

- Take home messages

Adsorbent Amended Wetlands

- The model captures NH4 reducton trend in zeolite- amended VSSF
- The model significantly overestimates COD reduction biochar-amended HSSF