Cost-Effective Hybrid Constructed Wetlands for Landfill Leachate Reclamation

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Outline

- Background, Hypotheses and Objectives
- Research Plan
- Practical specific benefits for end users
- Timeline
- TAG members
- Results from prior Hinkley Center support

Problems with Landfill Leachate

- Discharge to POTWs - common in Florida.
- High ammonia, recalcitrant organic matter and metal concentrations disrupt POTW processes.
- Hybrid vertical/horizontal subsurface flow constructed wetlands - cost-effective for onsite leachate treatment.

Douglas Road Landfill Leachate Treatment Wetland IN

(courtesy Jim Bays Jacobs Engineering)

CWs for Landfill Leachate Treatment

- Well documented for removal of organic compounds, nitrogen and trace metals.
- Reduces leachate volume by evapotranspiration.
- Year-round warm temperatures favor plant growth and biogeochemical processes that promote good performance.
- Hybrid Vertical Flow - Horizontal Flow Subsurface CWs enhances nitrification/denitrification.

Kodiak Treatment Wetland, Alaska
Design/build by CH2M HILL (1999)
- Landfill leachate

Questions from Hinkley Research Agenda

- What innovative technologies are available to engineer wetlands capable of treating landfill leachate?
- What cost-effective pretreatment processes should the leachate undergo to meet secondary drinking water standards?
- What processes, chemicals, or plants are best suited to mitigate the negative impact of humic acids as a pretreatment process at a landfill?

Guiding Hypotheses

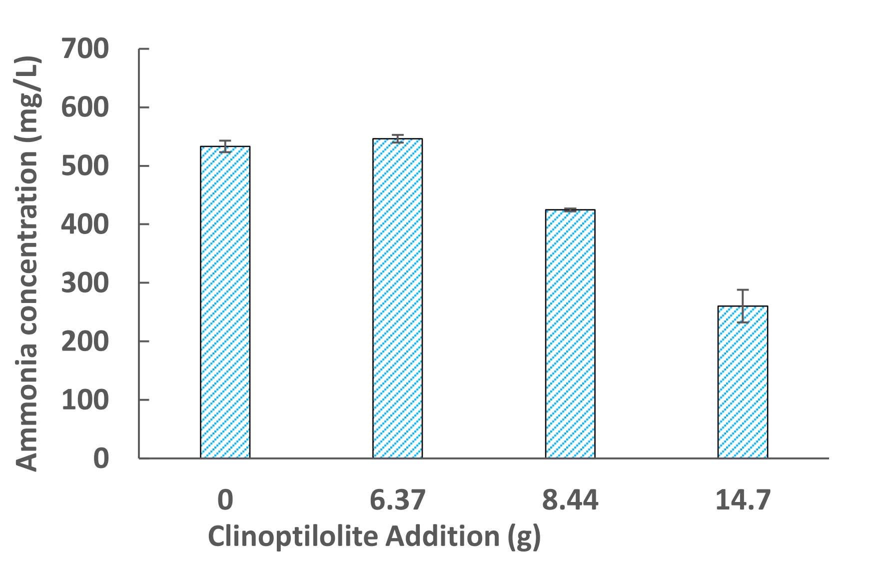
- Addition of zeolite, a natural mineral with a high NH_4^+ affinity, to VF-CW media reduces free ammonia toxicity to microorganisms and enhances biological nitrogen removal.
- Addition of biochar, a low-cost material produced from organic feedstocks such as wood chips, to HF-CW media enhances plant growth and retains recalcitrant organic matter, such as humic acids, to enhance its heterotrophic biodegradation.
- Adsorbent amended hybrid CWs can provide a cost-effective and low complexity landfill leachate treatment method compared with conventional onsite leachate treatment systems.

Research Objectives

- Compare conventional and adsorbent amended hybrid CW performance for landfill leachate treatment;
- Develop a numerical process model that can be used to predict the performance of the of the hybrid CWs under varying operational and leachate characteristics; and
- Evaluate post-treatment requirements for reuse applications.

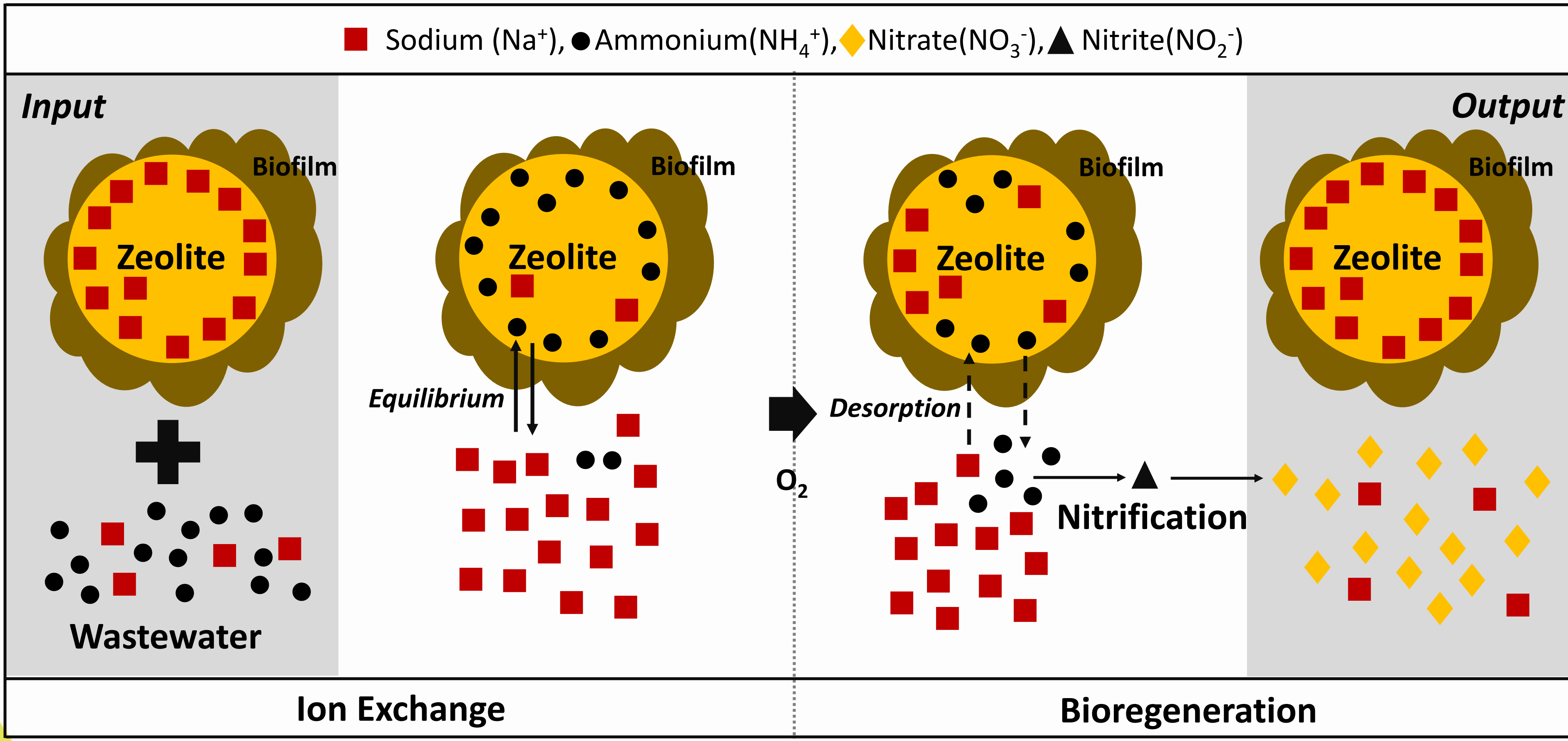
Natural Zeolite Minerals

- Porous aluminosilicate minerals.
- High cation exchange capacity and selectivity for NH_4^+ and K^+.
- Clinoptilolite - most abundant and commonly used zeolite.
- Chabazite - more expensive but higher NH_4^+ capacity.
- Widely used as chemical sieve, food and feed additive, odor control (cat litter).

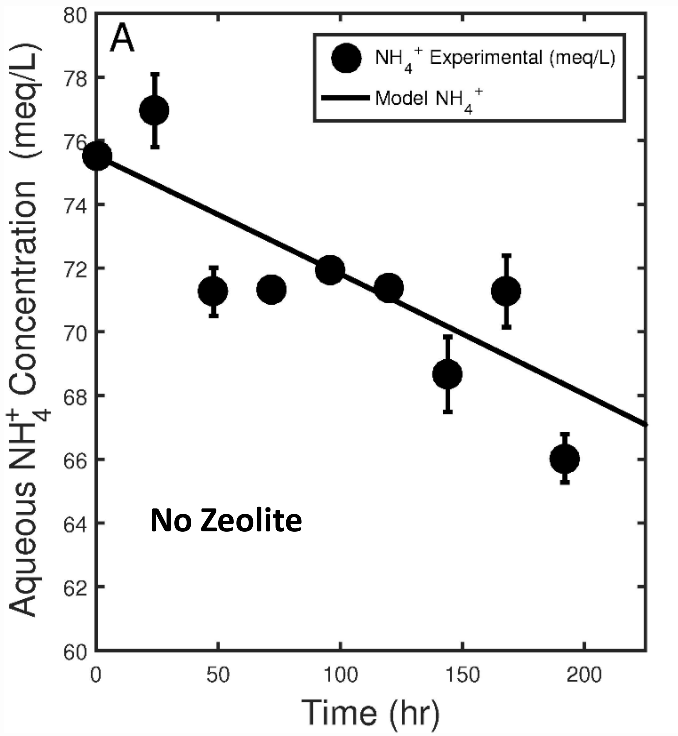


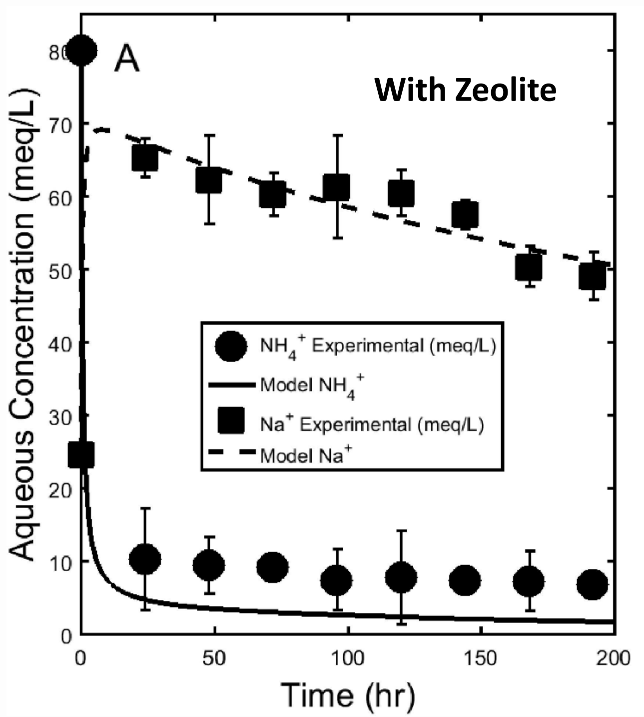
Ammonia removal in landfill leachate by clinoptilolite

Hybrid Adsorption Biological Treatment Systems (HABiTS)



Swine Wastewater Nitrification - NH_4^+

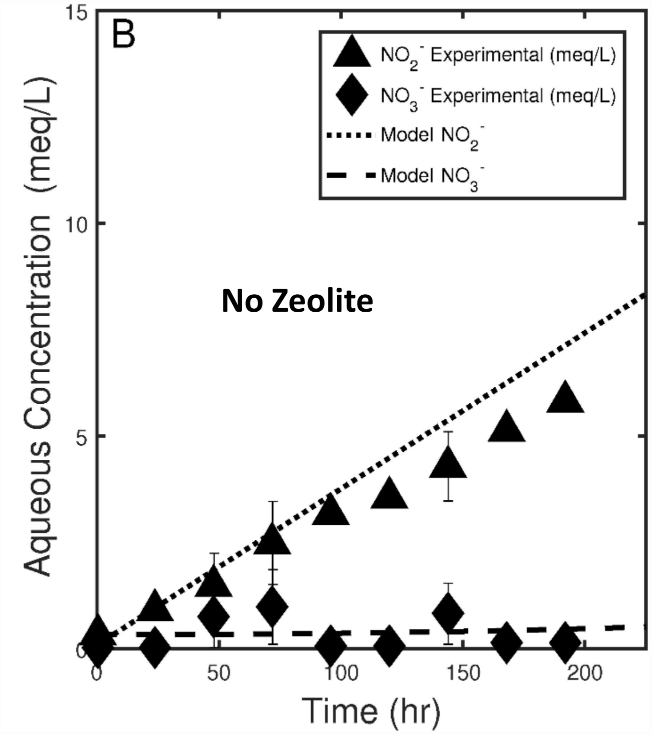


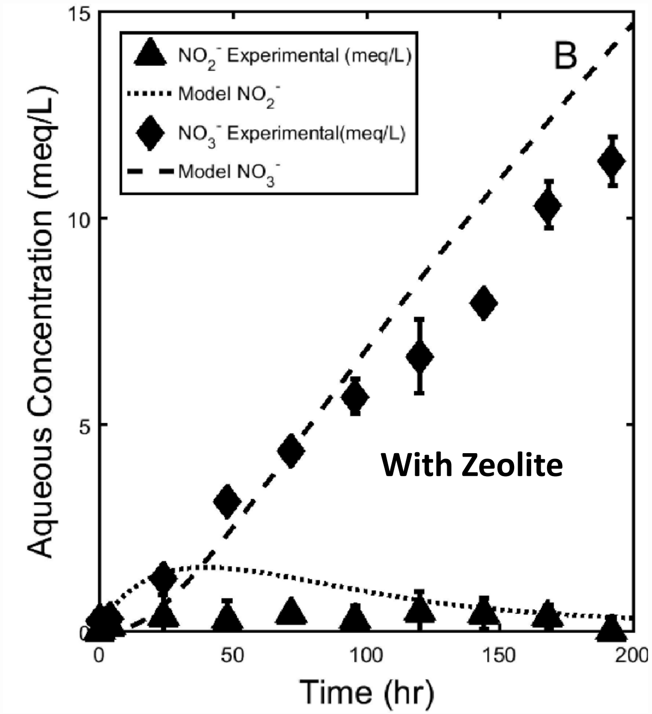


- Initial decrease of NH_4^+ and release of Na^+ followed by decline in Na^+ as bioregeneration takes place.

Aponte-Morales & Payne et al., (2018) *ES&T*.

Swine Wastewater Nitrification - NO_3^-

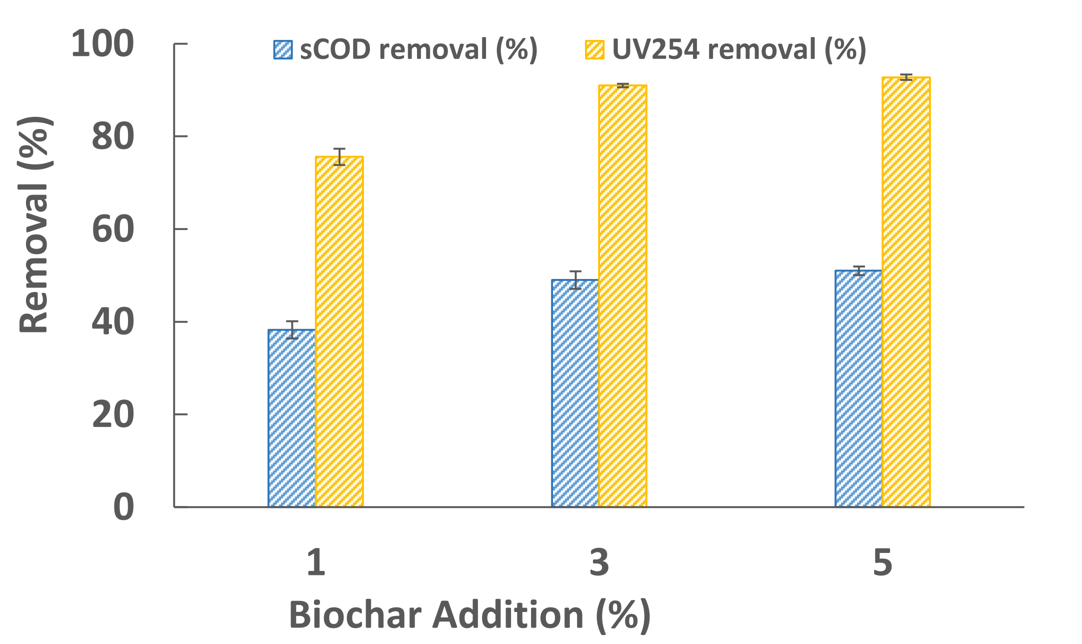




- Zeolite reduces free ammonia inhibition - doubles nitrification rate.
- Agreement with model of IX, surface diffusion, and FA inhibited nitrification.

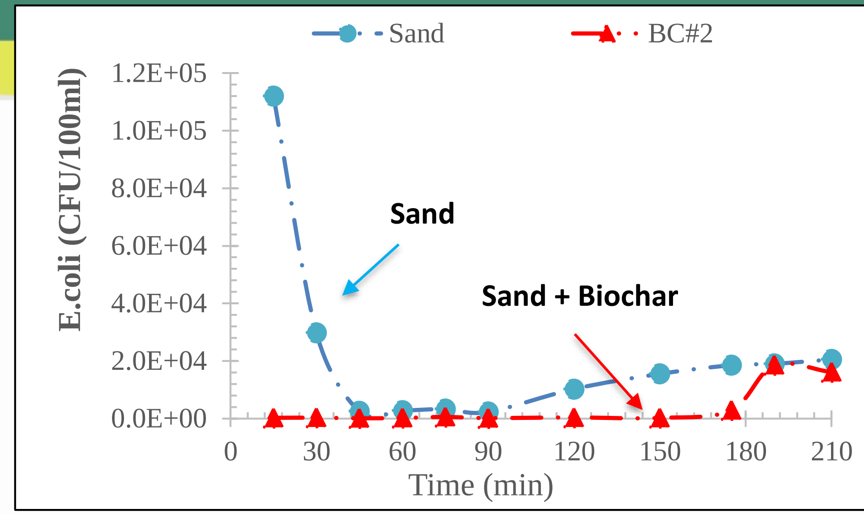
Biochar

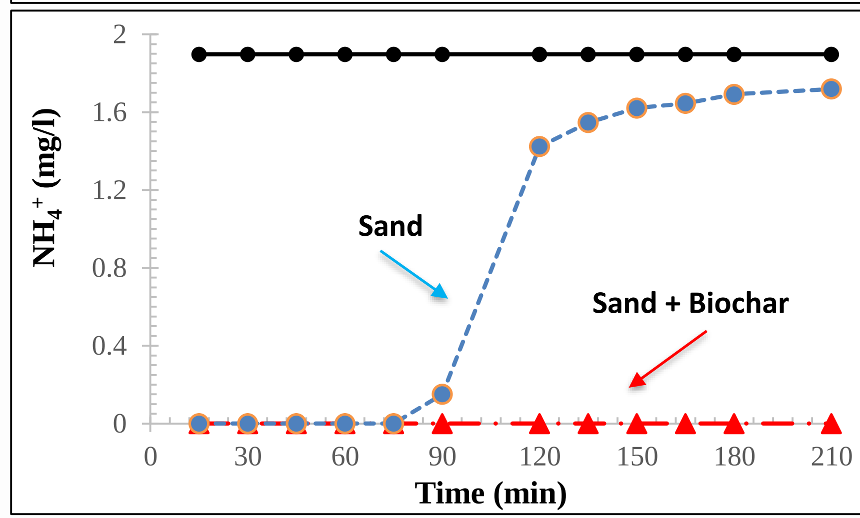
- Low-cost material produced by pyrolysis of organic feedstock (e.g., wood chips) at high temperature under O_2 limitations.
- High surface area, cation exchange capacity, moisture holding capacity.
- Improves productivity of agricultural soils.
- Enhances growth of beneficial microorganisms.



sCOD and UV254 removal in landfill leachate by biochar.

N and *E. coli* removal in biochar/sand columns





- Biochar significantly enhances ammonia and *E. coli* removal and nitrification in stormwater runoff.

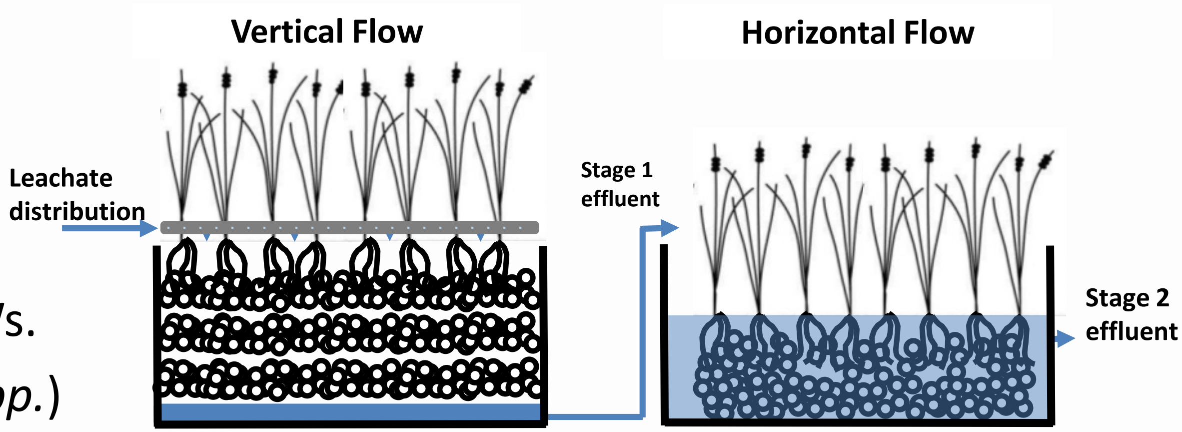
Hillsborough County's Southeast Landfill

- Class 1 landfill, waste tire processing, & composting operations.
- Partial onsite leachate treatment by activated sludge BNR with glycerol addition.
- BNR effluent and additional leachate hauled to county POTW.
- Pilot CWs will be housed in containment area adjacent to the leachate treatment.
- County interested in the potential implementation at adjacent wetlands.
- Operations staff enthusiastic about project.

Parameter		Units	Untreated Leachate	Treated Leachate
pH		mg/L	6.0-7.5	7.2-8.2
Cond.		umhos/cm	19,100-43,400	14,200-16,200
COD		mg/L	450-1000	600-2000
BOD_5		mg/L	10-35	2-44
Ammonia		mg/L	300-540	NP
Metals	Sb	µg/L	40-430	3
	As	µg/L	8-80	7
	Ba	µg/L	50-1300	57
	Cu	µg/L	30-190	12
	Pb	µgL	15-160	0.52
	Zn	µg/L	40-100	21

Pilot Study

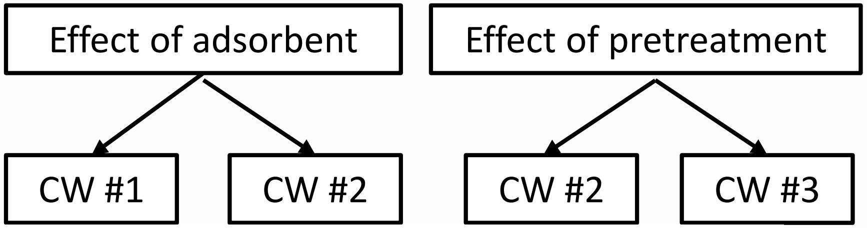
- Adsorption studies - to determine zeolite & biochar fractions with expanded clay.
- 3 pilot-scale hybrid VF-HF CWs.
- Planted with Cattail (*Typha spp.*) and bulrush (*Scirpus spp.*).



Pilot system schematic (not to scale).

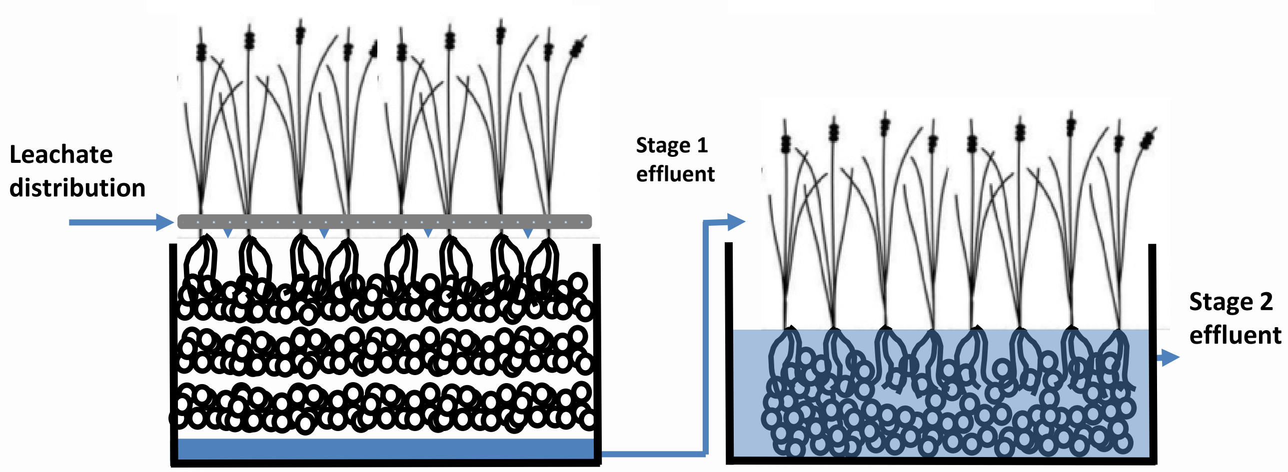
CW	V-CW medium	HF-CW medium	Feed
CW#1	LECA	LECA	Raw
CW#2	LECA + clinop	LECA + biochar	Raw
CW#3	LECA + clinop	LECA + biochar	Pre-treated

LECA= lightweight expanded clay aggregate



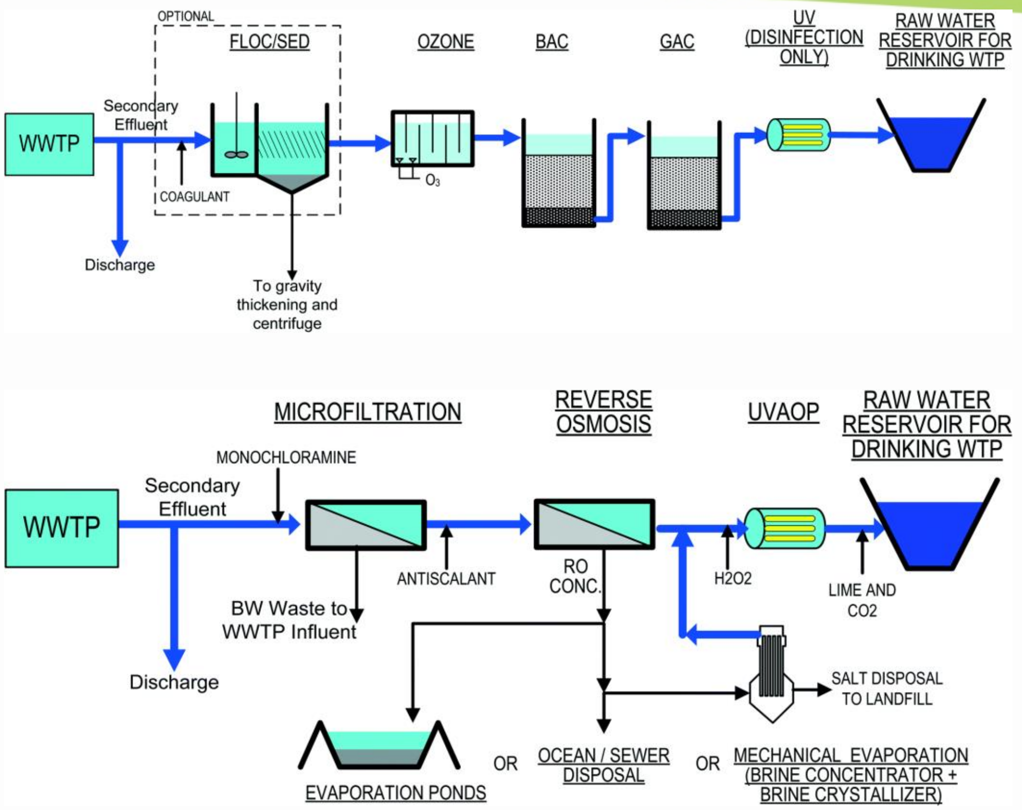
Pilot CW Monitoring & Modeling

- Measurements of pH, alkalinity, TSS/VSS, N and P species, sCOD, BOD5, UV254, full wavelength scans, metals.
- Logging sensors for water level, temperature and conductivity at hourly time steps.
- CW numerical process model to predict daily and long term N and organic carbon performance under varying operational, media and leachate characteristics.



Post Treatment Requirements for Reuse

- Techno-economic analysis with Hillsborough County as a case study.
- Consider irrigation, industrial (*e.g.,* cooling water), aquifer recharge, surface water augmentation, direct & indirect potable reuse.
- Post-treatment requirements - coagulation-flocculation-sedimentation-filtration, DAF, AOP, biofiltration, IX, GAC and membrane processes.



From Schimmoller *et al.* (2015) Triple bottom line costs for multiple potable reuse treatment schemes*, J. Royal Society Chem*.

Practical Specific Benefits for End Users

"The treatment of landfill leachate is a big issue both economically and environmentally for most landfills and wastewater treatment plants."

- Hinkley Center Research Agenda

- Hybrid CWs for onsite treatment have low complexity, low capital and O&M costs and proven long-term performance for removal of organic matter, nutrients and metals from landfill leachate.
- Addition of low cost adsorbent materials, clinoptilolite and biochar, can reduce system land requirements and improve effluent quality.
- Effluents from the proposed CWs can be safely discharged to POTWs or treated further to meet reclaim water standards.

Project Timeline and Milestones

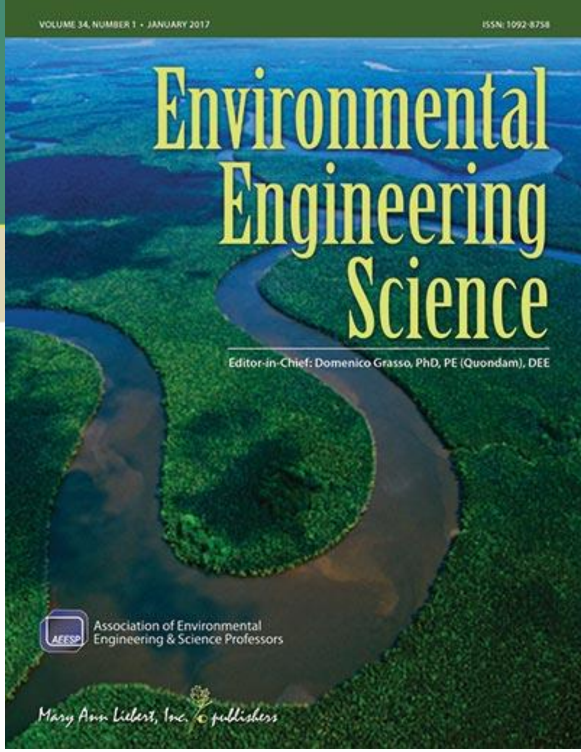
Task	Q1	Q2	Q3	Q4	Deliverable
Isotherm studies					Data for CW studies
CW construction & start up					Three pilot CWs
Pilot operation & modeling					Process model, Journal publication
Reuse assessment					Journal publication
Education & outreach					K-12 and USF students, professionals & community members
Quarterly & final reports	■	■	■	■	Reports for Hinkley and USF websites

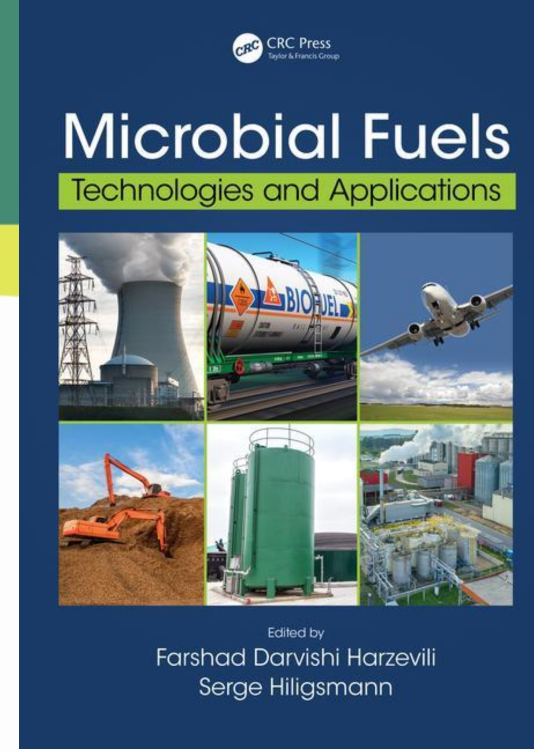
TAG Members

TAG Member	Position/Affiliation
James S. Bays	Technology Fellow, Jacobs Engineering
Kimberly A. Byer	MSW Management Division Director, Hillsborough County
Stephanie Bolyard	Research & Scholarship Prog. Manager, EREF
William J. Cooper	Prof. Emeritus, UC Irvine, Courtesy Prof. Environmental Engineering UF
Ashley Evans	Market Area Engineer, Waste Management, Inc., Florida
Melissa Madden-Mawhir	Senior Program Analyst, FDEP
Larry E. Ruiz	Landfill Operations Manager, Hillsborough County

Results of Prior Hinkley Center Support: Bioenergy Production from HS-AD of MSW

- Graduate students & postdocs - George Dick, Gregory Hinds, Eunyoung Lee, Phillip Dixon, Meng Wang
- Undergraduates - Ariane Rosario, Lensey Casimir, Paula Bittencourt, Eduardo Jimenez, Deborah Oliveira, Luiza Oliveira, Aleem Waris.
- Two peer reviewed journal articles, one book chapter, two master's theses.
- Conference presentations: ASCE World Environmental & Water Resources Congress, WEF/IWA Residuals and Biosolids Conference, ABWET Conference Paris, Global Waste Management Symposium. At least 6 poster presentations.
- Outreach at USF Engineering EXPO, Florida Water Festival and other events.
- Incorporation of topics into USF Environmental Engineering classes.
- Project website and videos on Hinkley Center website.
- Additional funding from National Science Foundation (PIRE, S-STEM, REU, RET programs), EU Biological Waste-to-Energy Grant, USF Student Green Energy Fund.





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- Hinds, G.R., Lens, P., Zhang, Q., Ergas, S.J. (2017) Microbial biomethane production from municipal solid waste using high-solids anaerobic digestion, In *Microbial Fuels: Technologies and Applications,* Serge Hiligsmann (Ed), Taylor & Francis, Oxford, UK.
- Lee, E., Bittencourt, P., Casimir, L., Jimenez, E., Wang, M., Zhang, Q., Ergas, S.J. (2019) Biogas production from high solids anaerobic co-digestion of food waste, yard waste and waste activated sludge, *Waste Management*, accepted for publication.
- Dixon, P.J., Ergas, S.J., Mihelcic, J.R., Hobbs, S.R. (in review) Effect of Substrate to Inoculum Ratio on Bioenergy Recovery from Food Waste, Yard Waste and Biosolids via High Solids Anaerobic Digestion, *Environmental Engineering Science*.

USF Campus Food Recovery Project

Phase 1-Source reduction: social marketing campaign

Phase 2- Feed hungry people: Charity organizations

Phase 3-Industrial uses: Anaerobic digestion

Landfill/Incineration

Questions?

reclaim
water • nutrients • energy

usf-reclaim.org