QUARTERLY PROGRESS REPORT

December 2019-February 2020

PROJECT TITLE: Cost-Effective Hybrid Constructed Wetlands for Landfill Leachate Reclamation

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WORK ACCOMPLISHED DURING THIS PERIOD

During the second quarter, progress was made on the following objectives: (i) further study of laboratory-scale sequencing batch reactors (SBRs) was carried out; (ii) pilot-scale hybrid constructed wetland (CW) systems have been designed; (iii) preliminary progress has been made on developing a conceptual model of the vertical and horizontal flow pilot-scale CWs; and (iv) SBR effluent quality and water reuse requirements were compared, and potential post-treatment methods have been identified.

LABORATORY-SCALE SEQUENCING BATCH REACTORS

Three SBRs were set up as described in the first quarterly report. One SBR contains lightweight expanded clay aggregate (LECA) media (C). One SBR has LECA mixed with clinoptilolite, a natural zeolite mineral with a high ion exchange capacity for ammonium (CZ). The third SBR contains LECA, clinoptilolite and biochar (CZB). The SBRs were seeded with biomass from the Valrico Wastewater Treatment Facility and operated with landfill leachate from Hillsborough County's Southeast Landfill. The SBRs are operated to achieve total nitrogen (TN) removal without external organic carbon addition through the following cycle: 1) fill, 2) anoxic react, 3) aerobic react, 4) decant, 5) idle. The systems were initially operated at a hydraulic retention time (HRT) of 14 days for 17 SBR cycles. During a second experimental phase, the HRT was reduced to 8.5 days. In the next phase, the HRT will be further reduced and glycerol will be added as a carbon source at the beginning of the anoxic phase.

COD Removal

In batch adsorption tests, biochar was found to have a high COD removal efficiency (see Quarterly Report 1). COD concentrations in the influent, end of the anoxic phase, and final effluent for the two HRTs are shown in Figure 1. CZB achieved the highest COD removals at both HRTs, suggesting that biochar retains recalcitrant organic matter in the SBR and increases its degradation. With HRT decreasing from 14 days to 8.75 days, the removal efficiencies in C, CZ and CZB decreased from 42%, 45% and 83% to 40%, 26% and 61%, respectively.

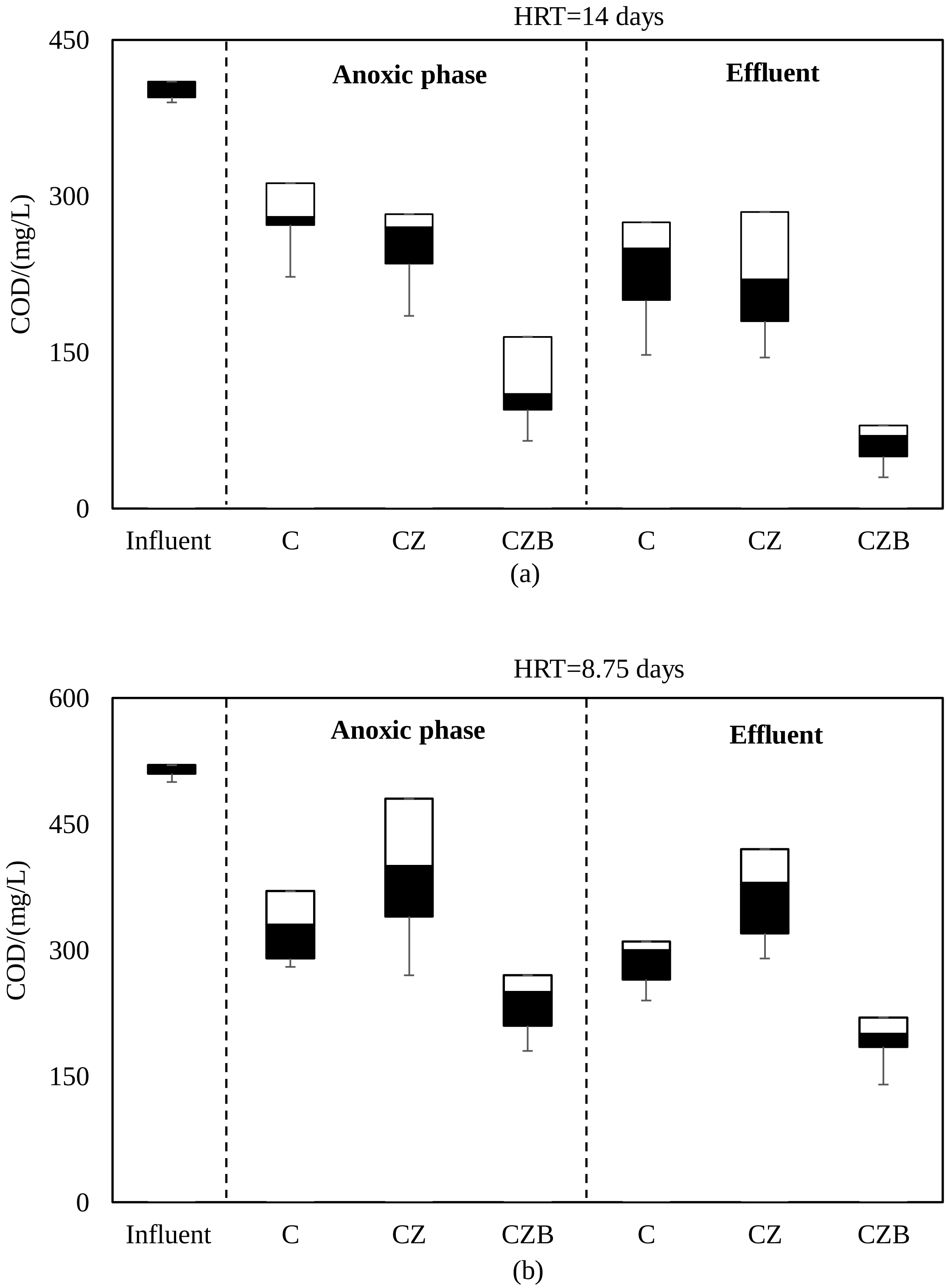


Figure 1. Box and whisker plots of COD concentrations in influent, anoxic phase and effluent from SBRs.

Color Removal

Leachate color is a serious problem, particularly for discharge to WWTFs that employ UV disinfection. In the first quarterly report, the effluent from CZB was colorless (HRT=14 days). Thus, in this second quarter period we decreased the HRT (8.75 days) to further observe the color removal performance. As shown in Figure 2, CZB, which contained zeolite and biochar, had excellent UV456 absorbance removal performance compared with other two SBRs.

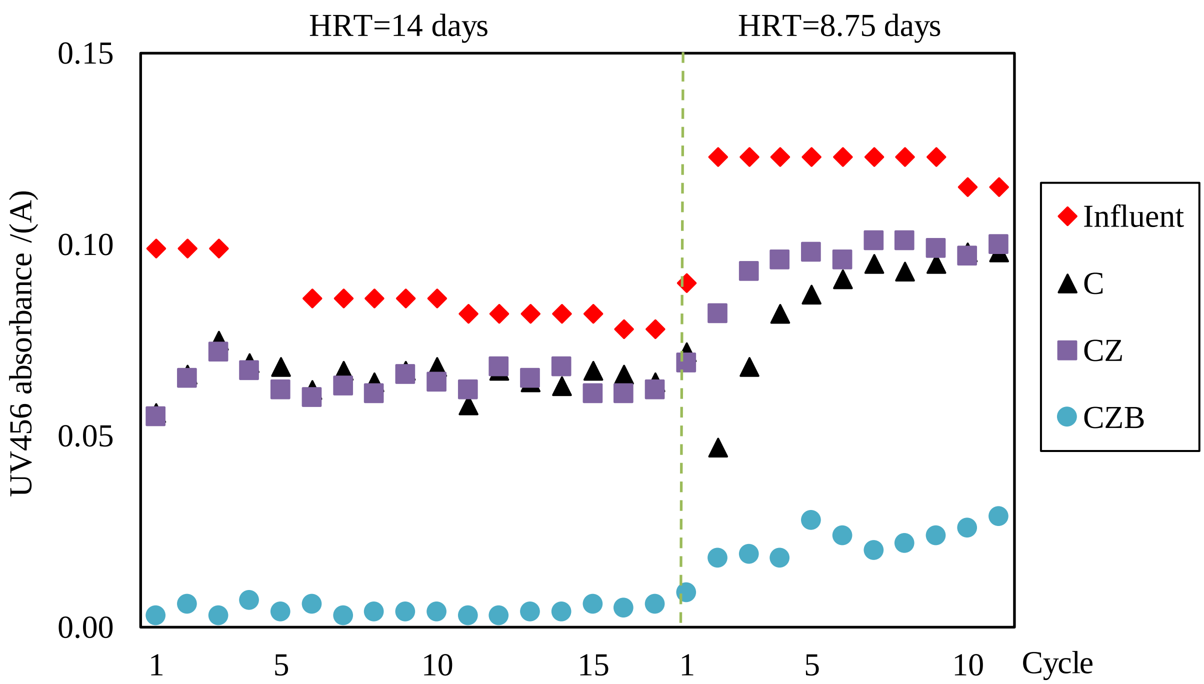


Figure 2. UV456 measurement in aerobic effluent during two HRT treatments.

Nitrogen Removal

NH_4^+ Removal

Zeolite had excellent NH_4^+ adsorption capacity in batch adsorption tests. As shown in Figure 3(a), at an HRT of 8.75 days, the presence of clinoptilolite resulted in significantly higher NH_4^+ removal during the anoxic phase (CZ and CZB) due to both adsorption and biodegradation mechanisms. However, after the aerobic stage, NH_4^+ was completely removed from the leachate in all three SBRs at both HRTs. We plan to further decrease the HRT and adjust the cycle time during the next quarterly period.

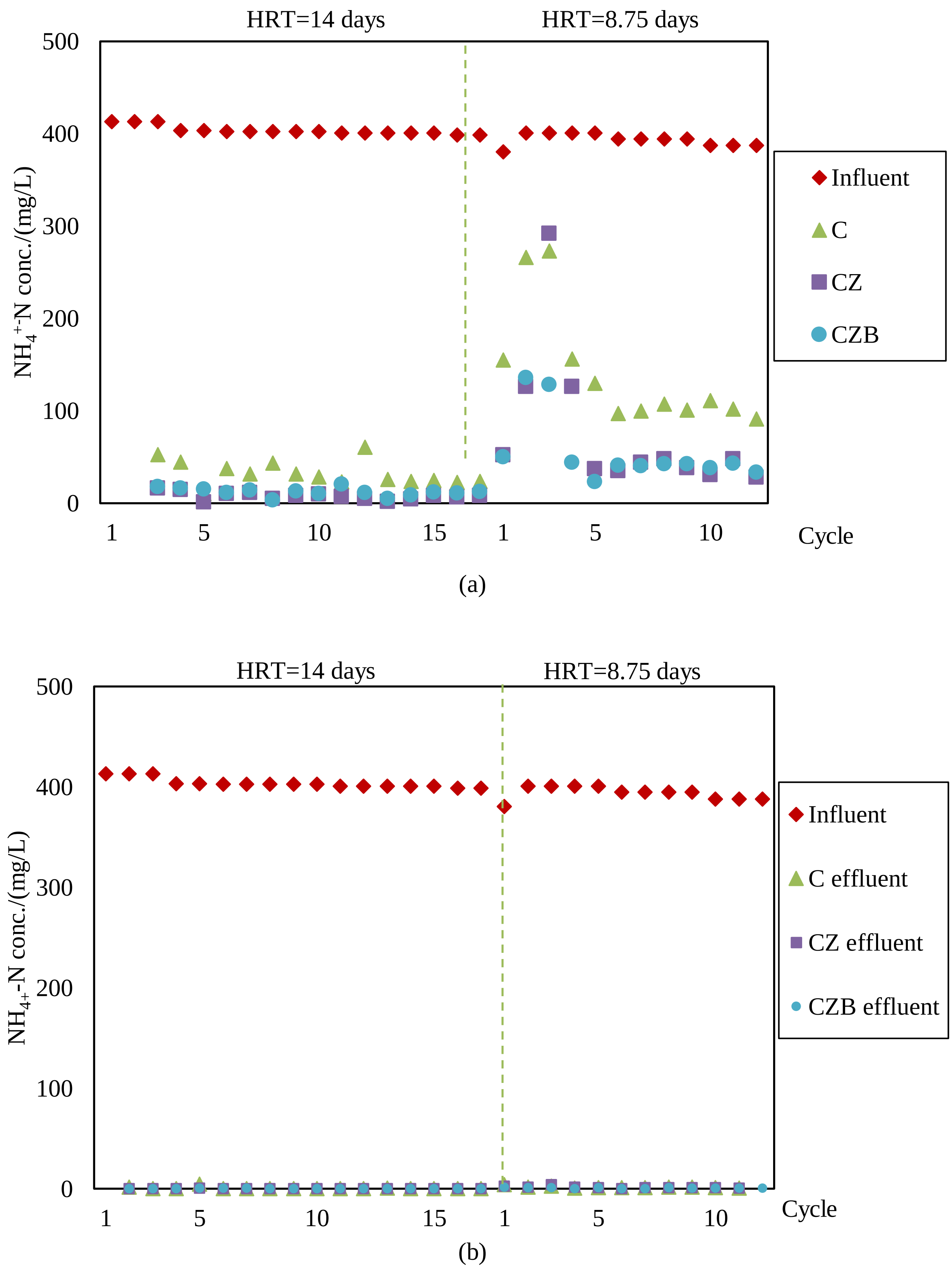
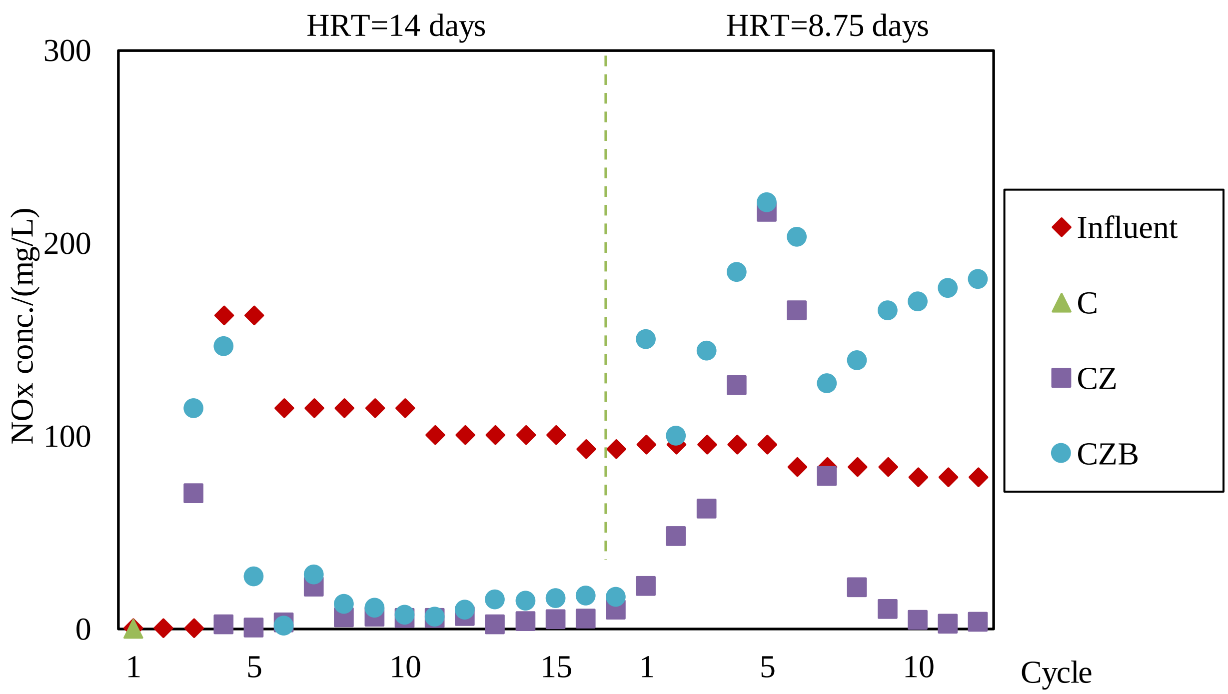


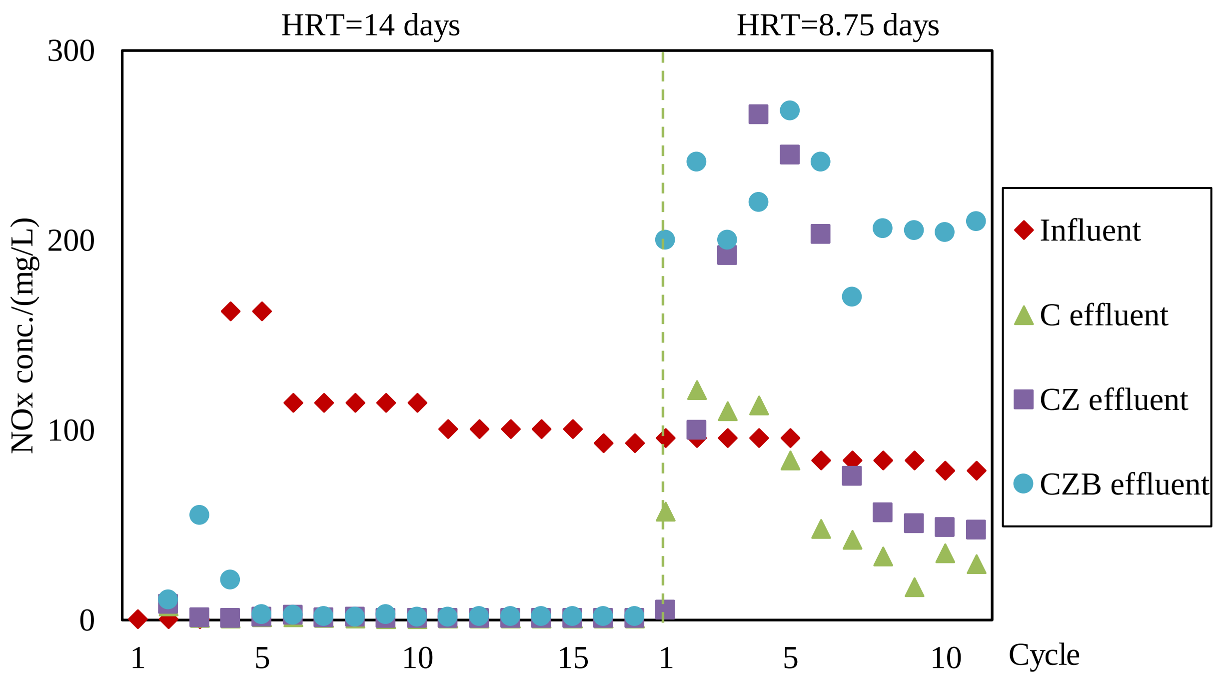
Figure 3. NH_4^+ concentrations: (a) anoxic phase; (b) effluent.

NOx (NO_2^- & NO_3^-) Removal

The results of NOx (NO_2^- + NO_3^-) measurements are shown in Figure 4. During the anoxic phase, denitrifiers use organic carbon in the leachate as an electron donor and NOx generated during the aerobic stage as an electron acceptor to produce N_2 gas, completely removing nitrogen from landfill leachate. Compared with CZB, C and CZ had better denitrification performance. Combing the data in Figure 4 with the COD removal results, it is hypothesized that organic matter adsorption by biochar results in electron donor limitations in CZB. During our next quarterly period we will test this hypothesis by adding an external carbon source, glycerol, to the SBRs at the beginning of the anoxic stage.



(a)



(b)

Figure 5. NOx concentrations: (a) anoxic phase; (b) effluent.

PILOT-SCALE HYBRID CONSTRUCTED WETLAND DESIGN

Two different configurations of hybrid constructed wetlands (CWs) were compared through a review of the literature: (a) vertical sub-surface flow constructed wetland (VSSF-CW) followed by horizontal sub-surface flow constructed wetland (HSSF-CW); (b) HSSF-CW followed by VSSF-CW (Table 1). Configuration (a) was selected for the pilot study based on cost, ability to achieve low effluent TN concentrations and lower complexity. A schematic of the proposed pilot hybrid CW is shown in Figure 6.

Table 1. Comparison of two CW configurations.

		(a) **VSSF + HSSF**	**(b)** **HSSF + VSSF**
Recirculation	Pump	Not needed	Needed
	Operation cost	Low	High (electricity consumption)
Electron donor addition		More	Less
Alkalinity addition		More	Less
Effluent dissolved oxygen concentration		Low	High

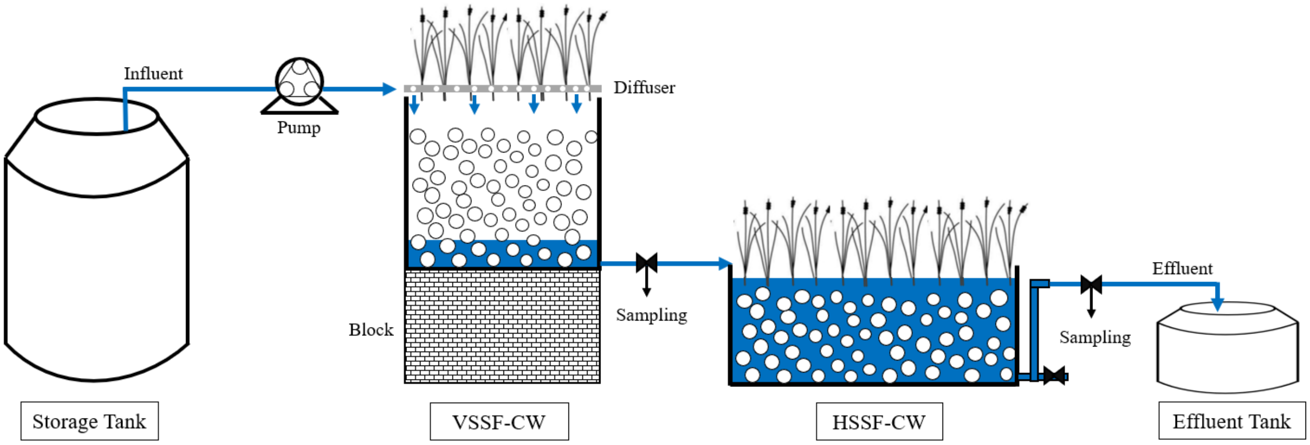


Figure 6. Pilot-scale hybrid CW system schematic (not to scale).

Two pilot-scale hybrid CWs will be set up at the Southeast Hillsborough County Landfill (Table 2). In the first Phase we will compare CW#1 and CW#2 with full-strength landfill leachate. In the second Phase, we will test CW#2 with treated leachate. Based on the literature review and laboratory-scale SBR results, the initial operating parameters for the CW systems were selected (Table 3). Tanks, pipes, pumps and media materials needed have been purchased. Cattail is one of the most commonly used plants in CWs treating landfill leachate. Cordgrass is highly tolerant to high salinity waters, such as leachate, therefore we are planning to combine those two plants into our CW systems. We have contact a company for the plants (Aquatic Plants of Florida).

Table 2. Media and influent for pilot-scale CWs.

Phase	**System**	**VSSF-CW**	**HSSF-CW**	**Feed**
Phase 1	CW#1	LECA	LECA	Raw leachate
	CW#2	LECA + Zeolite	LECA + Biochar	Raw leachate
Phase 2	CW#2	LECA + Zeolite	LECA + Biochar	Treated leachate

Notes: LECA= Light weight expanded clay aggregate.

Table 3. Initial operating parameters of hybrid CWs.

	VSSF-CW	**HSSF-CW**
Q (L/d)	80	
HRT (d)	3	5
V (L)	240	400
Aspect ratio (L:W, m)	1.0 (0.64 : 0.64)	1.8 (1.4 : 0.78)
Area (m^2)	0.4	1.1
Water depth (D, m)	0.6	0.36

PILOT OPERATION MODELING

A conceptual model is being developed for the VSSF-CW and HSSF-CW. The model outlines the hydrology, nitrogen and carbon transformations in the systems. This conceptual model will serve as the guide for developing the final mathematical model. The hydrologic model accounts for sources and sinks of water, via influent flow, precipitation and evapotranspiration. Variables such as bank loss, runoff, and groundwater infiltration are assumed to be negligible due to the controlled nature of the pilot system design. State variables that have been identified include volumetric flow, depth, and hydraulic loading. Inflow of leachate into the vertical flow will be a controlled function. State variables for the nutrient cycling model include concentrations and mass fluxes of ammonia, nitrate, nitrite, nitrogen gas, organic carbon and carbon dioxide. Further review of the literature will be the next step to conceptualize the effects of zeolite and biochar on the system. Additionally, established mathematical equations that describe each process will be added to the conceptual model.

WATER REUSE APPLICATIONS

Effluent quality from the laboratory-scale CZB SBR were compared with water reuse requirements for urban and agricultural irrigation, industrial reuse (e.g., cooling water) and aquifer storage and recovery (ASR) (Table 4). Based on the preliminary data, the conductivity is expected to be too high for reuse for irrigation, industrial cooling water, or aquifer recharge. Further treatment by Reverse Osmosis (RO) would be needed to reduce the salinity of the effluent. However, the treated effluent may be able to be discharged to a wastewater treatment facility or treated further to meet NPDES discharge standards. We are currently evaluating the cost of these options.

Table 4. Comparison of SBR effluent concentrations and water reuse requirements.

Parameters	**SBRs treated leachate**	**Water reuse requirement**			
		Urban reuse	**Agricultural reuse**	**Industrial reuse**	**Aquifer recovery**
pH	8.00	NS	7~8	7.9~8.7	6.5~9.2
NH_4^+-N (mg/L)	0.48	NS	NS	NS	NS
NO_3^--N(mg/L)	**210**	NS	NS	NS	**< 12**
TSS (mg/L)	< 0.01	< 5	< 5	< 5	< 20
BOD_5 (mg/L)	< 10	< 20	< 20	< 20	< 20
Electrical Conductivity (µs/cm)	**15,740**	NS	**< 1,360**	**< 1,120**	**<1,000**

Notes: NS= not specified.

TAG MEETING

The first TAG meeting was held on November 21, 2019. Participants included the PIs, graduate students, TAG members, and other interested parties.

Graduate students:

Name	Degree program	Department	Email
Xia Yang	PhD	Civil & Environmental Engineering	xiayang@mail.usf.edu
Bisheng Gao	MS	Civil & Environmental Engineering	bisheng@mail.usf.edu
Lillian Mulligan	MS	Civil & Environmental Engineering	lillianm@mail.usf.edu
Xufeng (Alex) Wei	MS	Civil & Environmental Engineering	xufengw@mail.usf.edu

TAG member attendees:

Name	Position/Affiliation	Email
James S. Bays	Technology Fellow, Jacobs Engineering	Jim.Bays@jacobs.com
Kimberly A. Byer	Solid Waste Management Division Director, Hillsborough County	ByerK@hillsboroughcounty.org
William J. Cooper	Prof. Emeritus, UC Irvine (Courtesy Prof. UF)	wcooper@uci.edu
Ashley Evans	Market Area Engineer, Waste Management, Inc., Florida	aevans19@wm.com
Melissa Madden-Mawhir	Senior Program Analyst, FDEP	Melissa.Madden@FloridaDEP.gov
Larry E. Ruiz	Landfill Operations Manager Hillsborough County	RuizLE@hillsboroughcounty.org

Additional attendees:

Name	Position/Affiliation	Email
Wester Henderson	Research Coordinator, Hinkley Center	Wester.henderson@essie.ufl.edu
Kristen Waksman	Process Control Engineer, Hillsborough County	WaksmanK@hillsboroughcounty.org
Luke Mulford	Water Quality Manager, Hillsborough County	MulfordL@HillsboroughCounty.ORG
Marcus Moore	Plant Supervisor, Valrico Advanced WWTP, Hillsborough County	MooreM@hillsboroughcounty.org

TAG members unable to attend:

Name	Position/Affiliation	Email
Stephanie Bolyard	Research and Scholarship Program Manager, EREF	sbolyard@erefdn.org

Ashley Danley-Thomson	Assistant Professor, Florida Gulf Coast University	athomson@fgcu.edu

Link to TAG presentation: TAG presentation slides are posted at http://constructed-wetlands.eng.usf.edu/. The recorded presentation is upload at http://constructed-wetlands.eng.usf.edu/videos/2019-11-21_10.04_TAG.Constructed.Wetlands.for.Landfill.Leachate.Ergas.mp4.

Metrics:

1. List research presentations resulting from (or about) this Hinkley Center Project.

An abstract was submitted to the American Ecological Engineering Society annual meeting.

A MS student, Bisheng Gao, will defend his MS thesis on the lab scale SBR results on March 11, 2020 at 3:00 pm on the USF campus. Please contact Dr. Ergas for more information.

2. List who has referenced or cited your publications from this project.

Nothing to report yet.

3. How have the research results from this Hinkley Center project been leveraged to secure additional research funding? What additional sources of funding are you seeking or have you sought?

USF departments of Integrative Biology, Geoscience, and Civil & Environmental Engineering recently received a funding from the NSF for an S-STEM scholarship grant. The grant will fund MS students who are interested in the broad topic of "managing the nitrogen cycle." Lillian Mulligan has applied for an S-STEM scholarship.

A research proposal was submitted for internal funding from USF Strategic Investment Pool for funds for a furnace to produce our own biochar from various feedstocks.

4. What new collaborations were initiated based on this Hinkley Center project?

Scott Knight is the co-owner and VP of Wetland Solutions (http://www.wetlandsolutionsinc.com/), has been involved in a number of large treatment wetlands in Florida. He visited our laboratory and discussed potential collaborations.

Andre Dieffenthaller, P.E., Vice President, Hazen and Sawyer, is currently leading a complimentary study on the impact of landfill leachate on Hillsborough County's Valrico Advanced Wastewater Treatment Plant. The team has been in touch with him to discuss potential synergies between the two studies.

5. How have the results from this Hinkley Center funded project been used (not will be used) by the FDEP or other stakeholder?

Nothing to report yet.

References

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