

SUMMARY: SAFE DISCHARGE OF LANDFILL LEACHATE TO THE ENVIRONMENT, YEAR TWO

Daniel E. Meeroff (PI)¹ and Fred Bloetscher (Co-PI)

Some closed or partially closed landfills still produce important quantities of leachate, but instead of blending this material with active Class I leachate for disposal, there may be better alternatives. If a relatively inexpensive way to pretreat the leachate and safely dispose of it onsite can be developed, a giant step toward the potential for zero liquid discharge can be achieved. FAU has pioneered the advancement of landfill leachate treatment systems using the photochemical iron-mediated aeration process and the TiO₂ photocatalytic process at laboratory scale in previous research funded by the Hinkley Center, which has led to the development of reactor prototypes for pilot scale testing. The objective of the proposed research is to test a prototype photooxidative reactor at pilot scale for the removal of COD/BOD, heavy metals (i.e. arsenic, lead, and iron), ammonia, color, chlorides, and pathogens to determine the feasibility of safely discharging or reusing this leachate as a resource, such as irrigation for top caps and side slopes.

In previous work funded by the HCSHWM, 23 different engineering alternatives for long-term leachate management were evaluated (Meeroff and Teegavarapu 2010). For on-site treatment to work, some form of aerobic treatment would be expected to reduce leachate strength prior to discharge. However, biological systems are not well-suited for the removal of bio-toxics from water and are inefficient in dealing with wastes of varying quality, such as leachate. Thus post-treatment, using constructed wetlands, combined physicochemical treatment, or evaporation systems, would then be required. Unfortunately, technologies such as activated carbon and certain advanced treatment processes, such as ozone, do not adequately address inorganics, and membrane systems or air stripping merely transfer organics to another phase or create a side stream, like concentrate brine that cannot be discharged readily. Furthermore, multiple barrier systems are complicated to operate, costly, and generally inefficient. For on-site treatment options, the most effective strategies involve technologies that can destroy different classes of harmful contaminants all at once, without producing adverse byproducts and residuals.

Fortunately, FAU has been working to address this need for sustainable, economical options for routine leachate treatment and safe discharge to the environment by investigating energized processes, such as photocatalytic oxidation. In our previous studies involving the use of photocatalytic oxidation technologies for treatment of landfill leachate, we were able to demonstrate destruction of 1400 – 2500 mg/L of COD in just 24 hours. But these leachates had initial COD concentrations on the order of 6,000–10,000 mg/L, so if we start with a less concentrated material (e.g. partially closed landfill leachate), it should be possible to completely destroy the COD with the added potential of meeting the requirements of F.A.C. 62-302 for metals and 62-777 for surface water target levels or even meeting the less stringent industrial water quality guidelines for onsite beneficial reuse of this material.

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PROGRESS REPORT

(June 2015)

Project Title: Safe Discharge of Landfill Leachate to the Environment

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Students: Joseph Lakner, Neil Coffman

The experiments conducted during the period of March 2015 – June 2015 focused on using a falling film photocatalytic pilot scale reactor to remove COD/BOD, ammonia, heavy metals, color, and pathogens from leachate. The goal is to determine the appropriate conditions (catalyst dosage, UV intensity, pH, and temperature) to maximize removal of the aforementioned water quality parameters. Once optimal conditions are found, the cost of treatment in dollars per gallon will be determined.

15 g/L TiO₂ with Acid Addition

Literature suggests that the TiO₂-UV photocatalytic process is more efficient at low pH. Therefore, acid addition was tested, since the previous experiments showed a slowing of the reaction kinetics compared to the expected rate due to pH readings around 9.3 potentially slowing the observed rate of reaction. Acetic acid was selected for the purpose of reducing the pH without using a hazardous material for pH adjustment. Additionally, the temperature at which the reactor was run in previous tests was increased for this experiment to better simulate realistic conditions (~25°C), as shown in Figure 1.

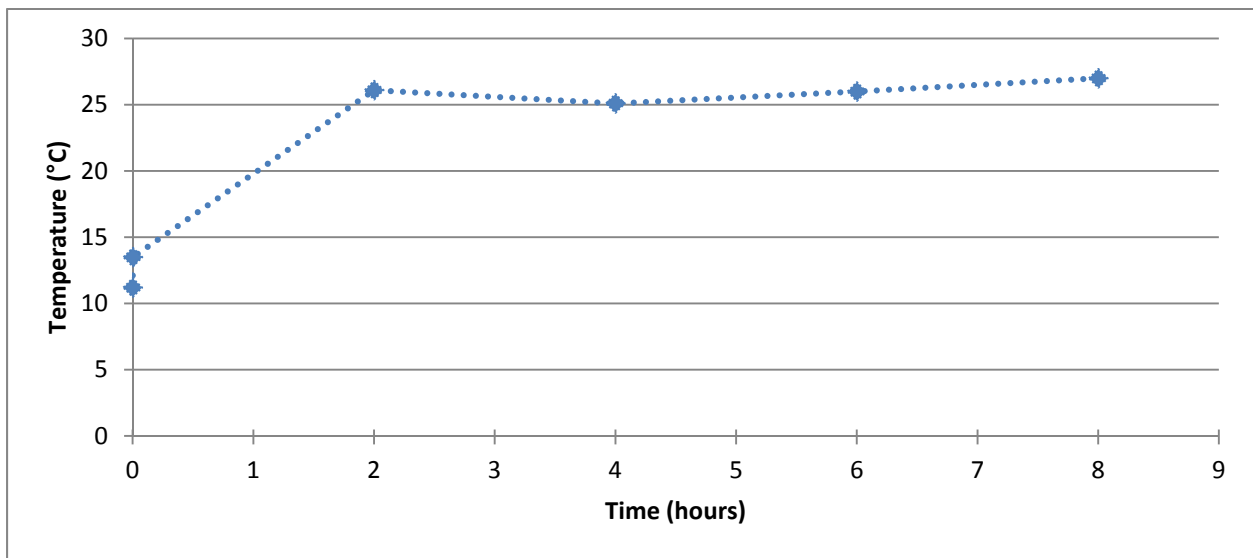


Figure 1: Temperature for 15 g/L falling film reactor experiment.

The addition of acetic acid was problematic for determining COD levels in the leachate since acetic acid itself is a weak organic acid. Therefore, the pH adjustment was merely temporary and quickly increased back to basic after initially dropping momentarily (see **Error! Reference source not found.**). Also, the measurement of COD was confounded by the presence of acetate ion. Clearly, another acid should be used if acid addition is tried again.

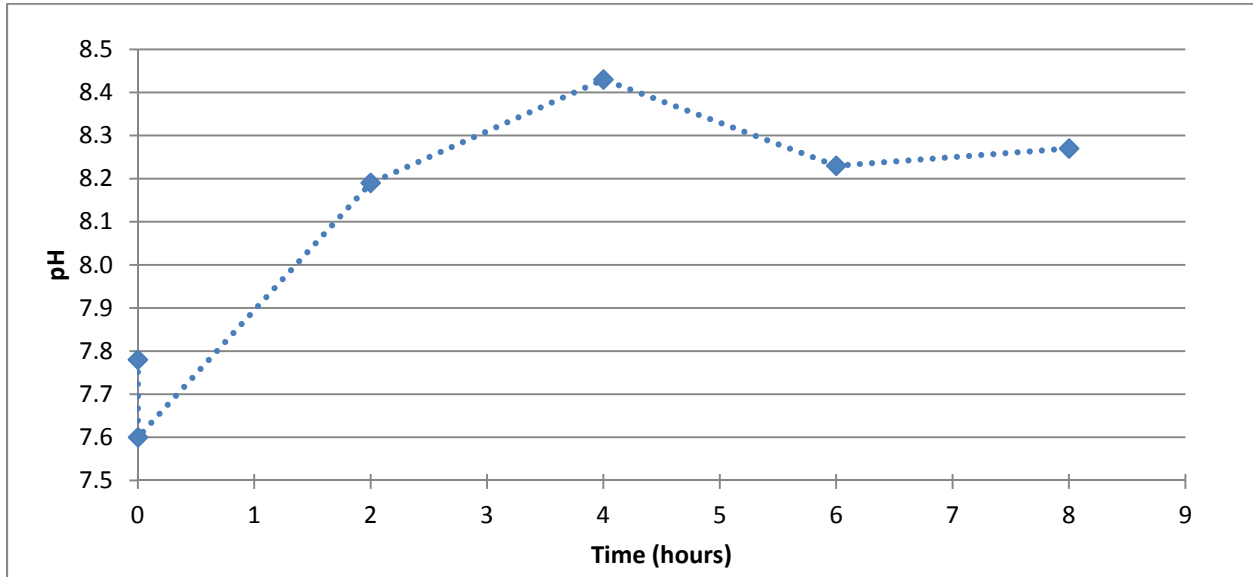


Figure 2: pH for 15 g/L falling film reactor experiment

The alkalinity was reduced at a constant rate to about 42 percent after 8 hours of treatment (Figure 3).

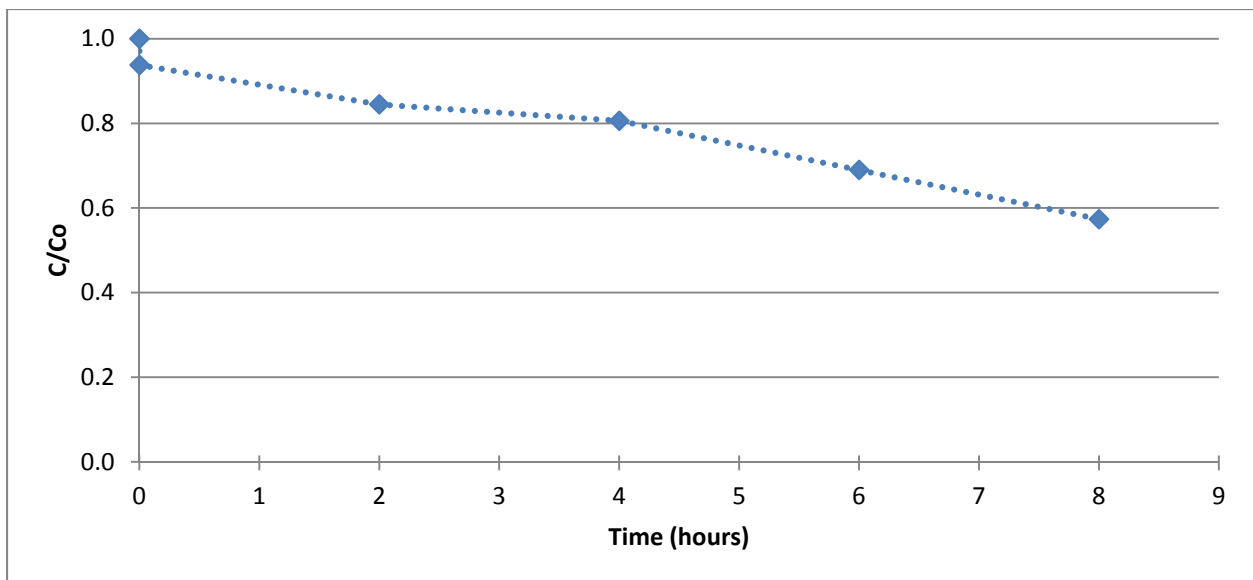


Figure 3: Alkalinity for 15 g/L falling film reactor experiment

Calcium hardness was initially reduced by 38 percent with the addition of the TiO₂, presumably by deposition onto the catalyst surface. An additional decrease of 37 percent occurred in the first 4 hours of TiO₂-UV treatment, which was asymptotic to 8 hours (Figure 4).

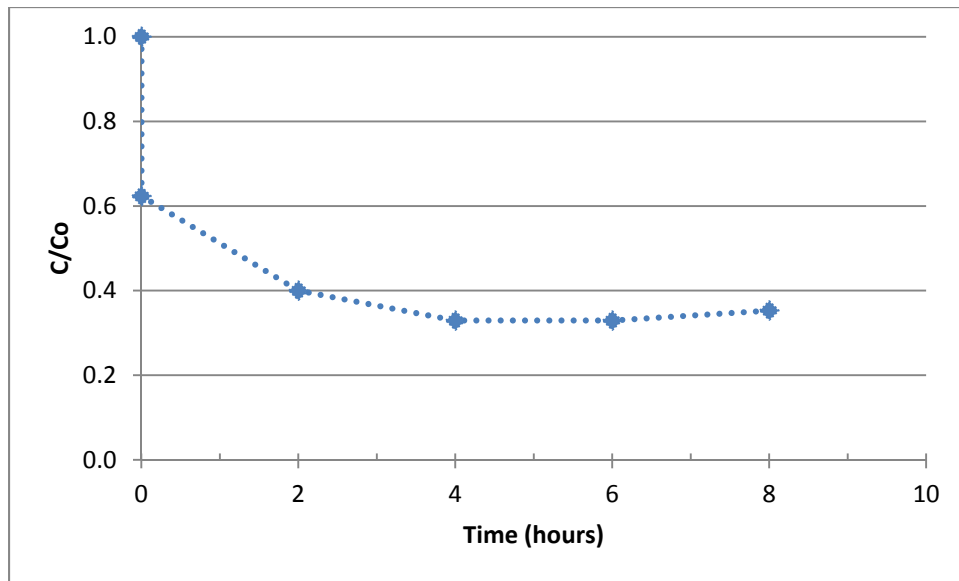


Figure 4: Calcium Hardness for 15 g/L falling film reactor experiment

Kinetics Testing

Using a threshold of 0.7 for acceptable correlation coefficients, the following reactions rates were found. COD (Figure 5) was found to be reduced in accordance with a first order reaction. Alkalinity (Figure 6) was removed at a zero order reaction. While calcium hardness seemed to follow a second order removal (Figure 7).

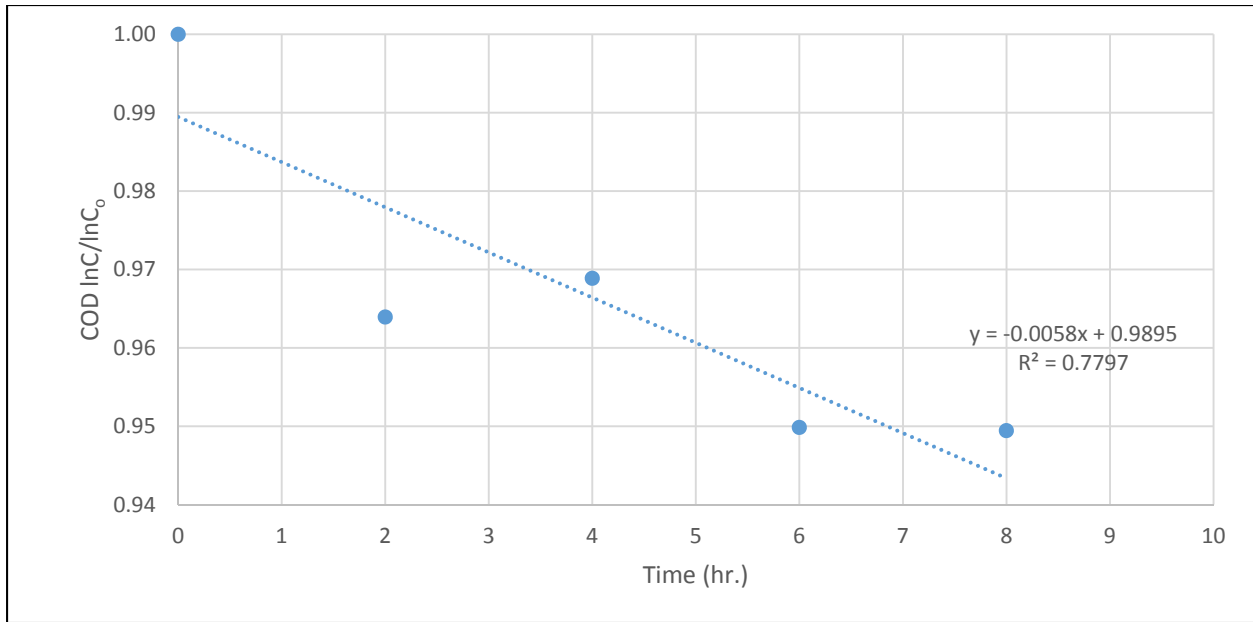


Figure 5: COD reaction order kinetics plot (04/03/2015)

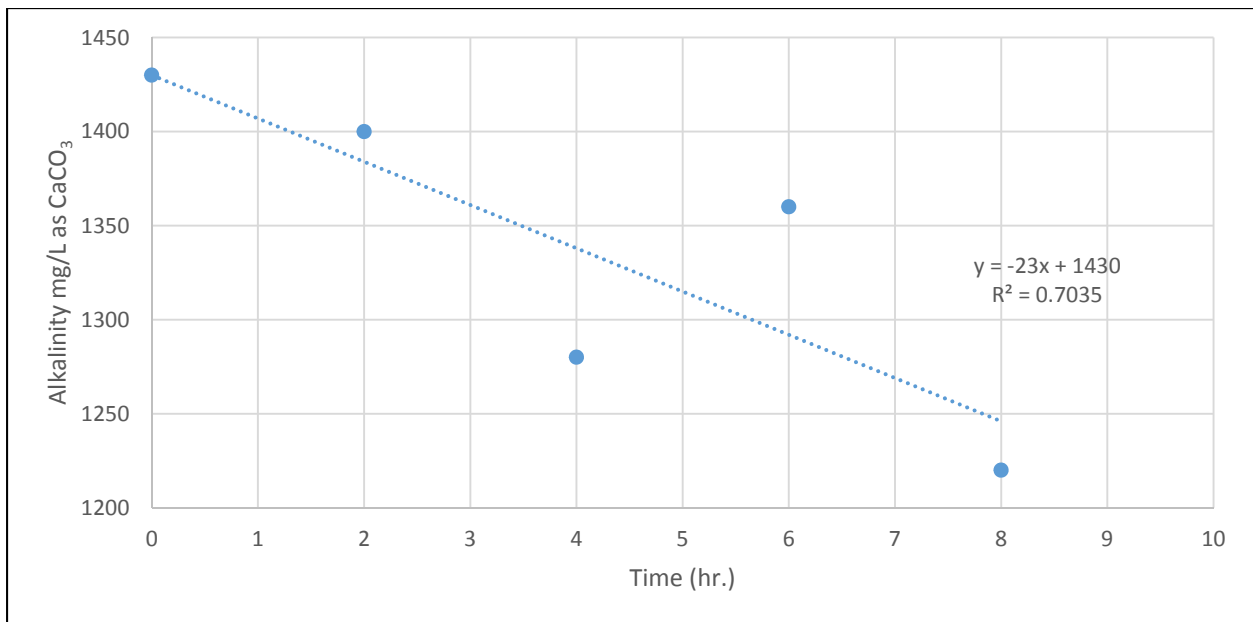


Figure 6: Alkalinity reaction order kinetics plot (04/03/2015)

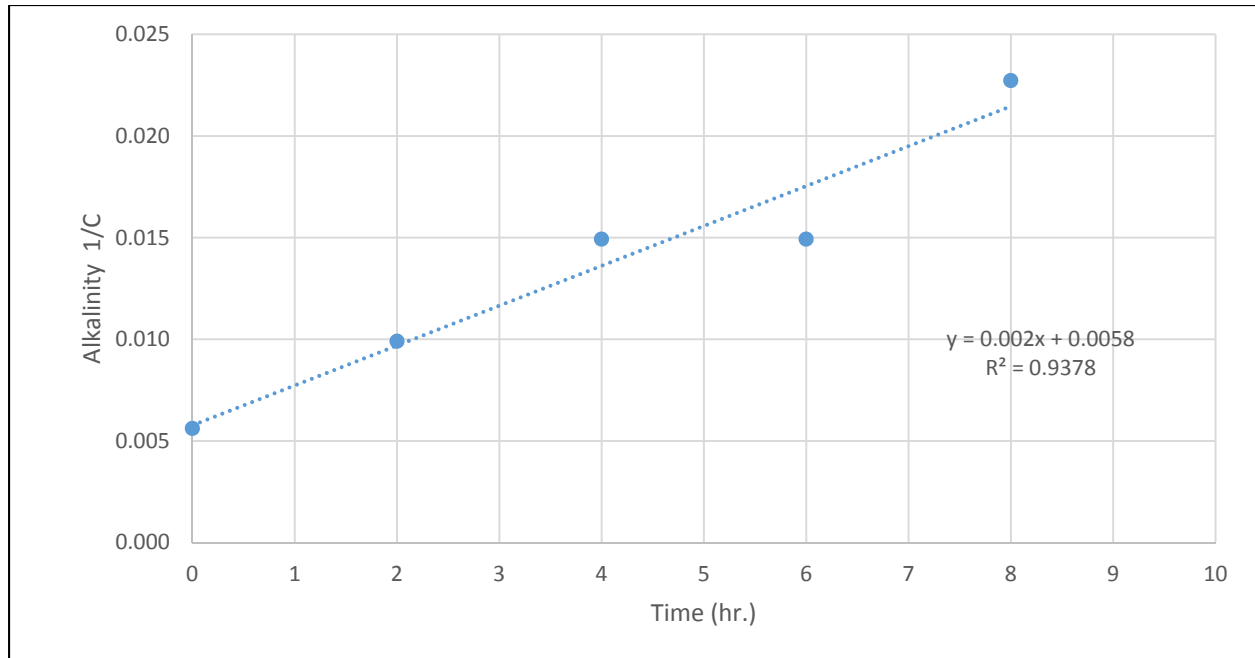


Figure 7: Calcium hardness reaction order kinetics plot (04/03/2015)

20 g/L TiO₂ with Lime Addition Pretreatment

Lime pretreatment was used to remove calcium, which was thought to be bonding with the titanium dioxide and thereby reducing the effectiveness of the photocatalytic treatment. The calcium hardness was very high at the start of the test but was removed rapidly (38%) initially only with the addition of titanium dioxide. Therefore, xx grams of lime was added and mixed for x minutes. The pH climbed to 11.5 – 12.0. Under these conditions, COD was reduced by 53%, and ammonia was reduced by 23%, which was an unexpected result due to the high pH. The results are plotted over time in Figure 8.

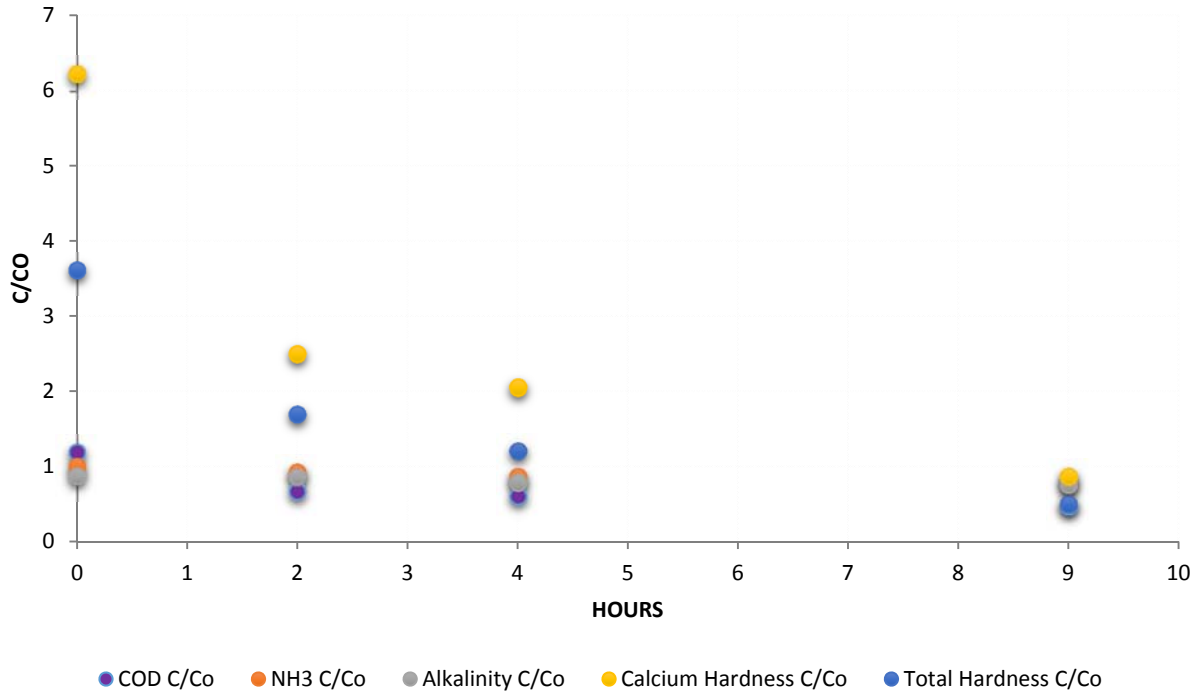


Figure 8: COD, NH₃, Alkalinity, Calcium and Total hardness concentrations over time (05/28/2015) using the falling film reactor with 50-W lamp and 20 g/L TiO₂.

Critical Orifice Advanced Oxidation Process Post-Treatment with 1” Venturi

A pilot scale version of the critical orifice advanced oxidation process was obtained, but the first trials were relatively unsuccessful. The rust from the stainless steel pump (Speck Pump Y-2951-W-MK) housing seemed to be interfering with the magnet chamber and the entrained oxygen bubbles. Therefore, the pump was replaced (insert specs here). For this experiment, the leachate water temperature varied from 18.5 – 22.0°C. However, after 15 minutes of treatment, the pH increased rapidly (Figure 9), and the COD (Figure 10), ammonia (Figure 11), alkalinity (Figure 12), and calcium (Figure 13) showed only minimal removal, if any.

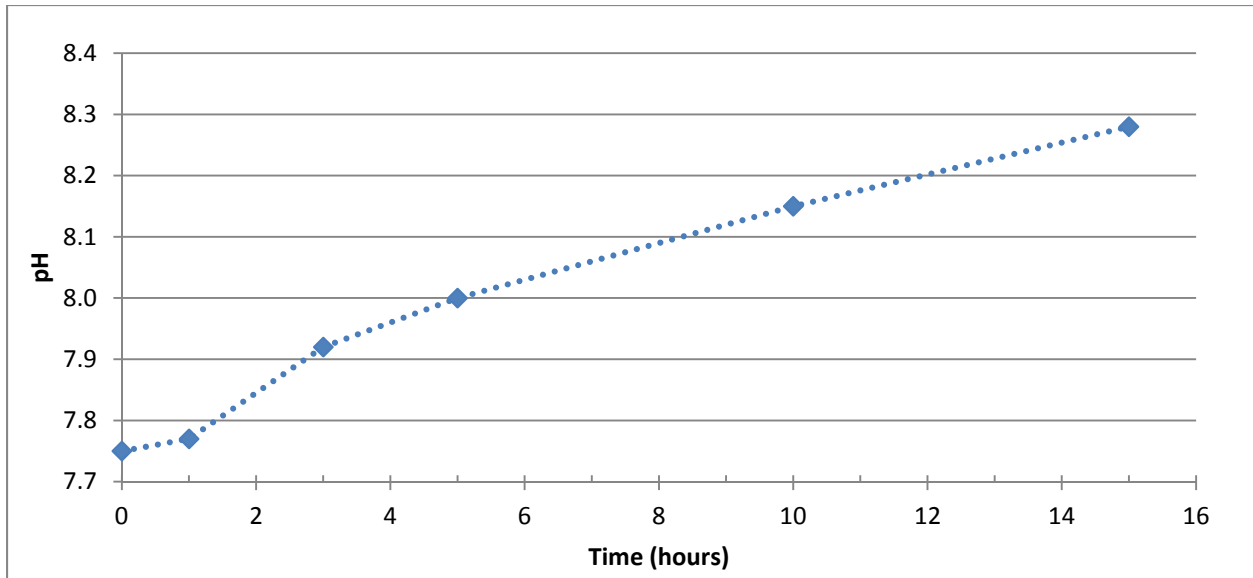


Figure 9. pH over time for the critical orifice advanced oxidation process post-treatment with 1" venturi (05/01/2015).

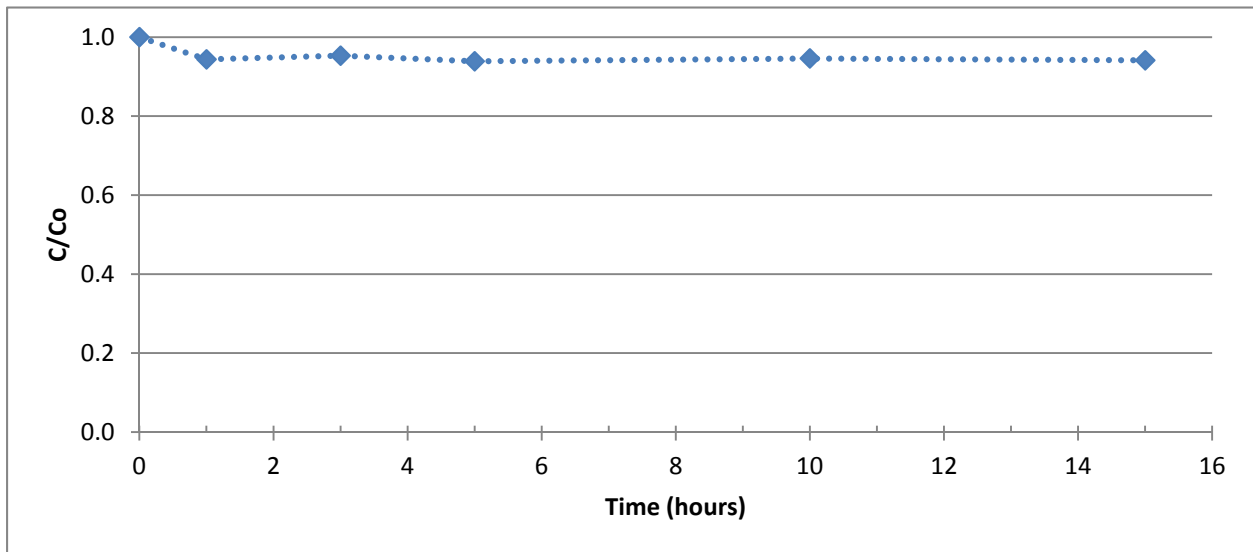


Figure 10. COD over time for the critical orifice advanced oxidation process post-treatment with 1" venturi (05/01/2015).

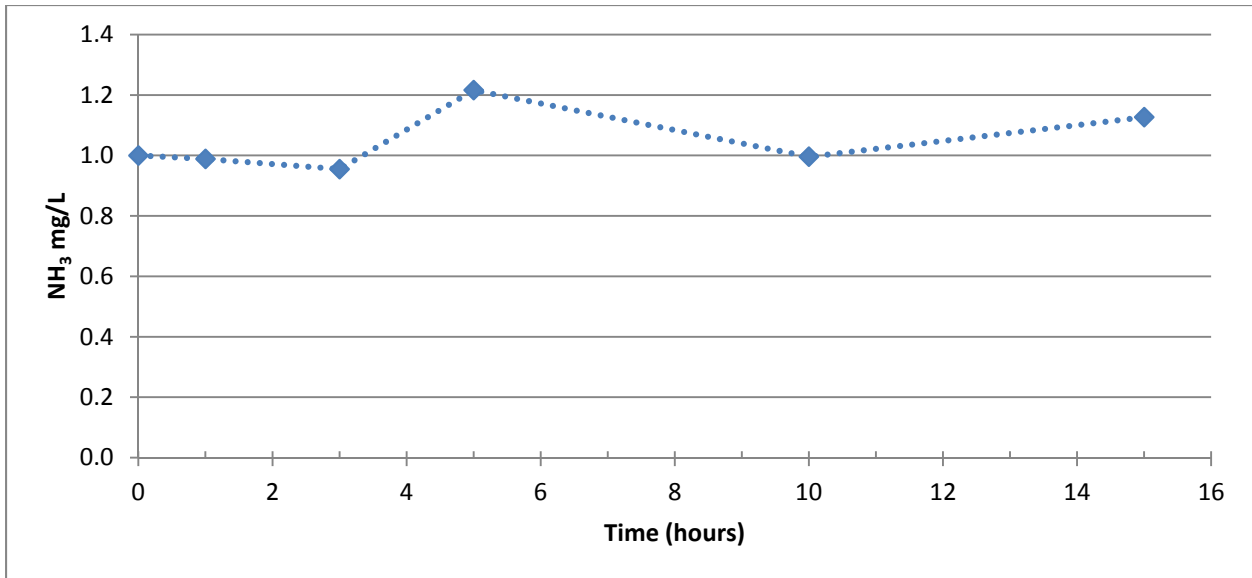


Figure 11. Ammonia over time for the critical orifice advanced oxidation process post-treatment with 1” venturi (05/01/2015).

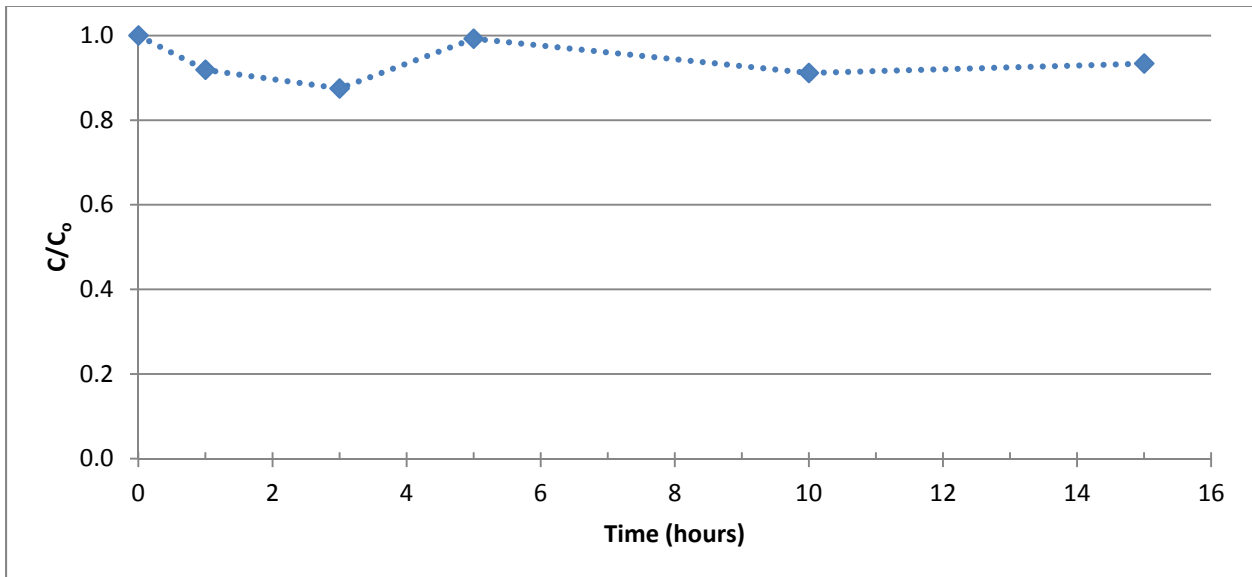


Figure 12. Alkalinity over time for the critical orifice advanced oxidation process post-treatment with 1” venturi (05/01/2015).

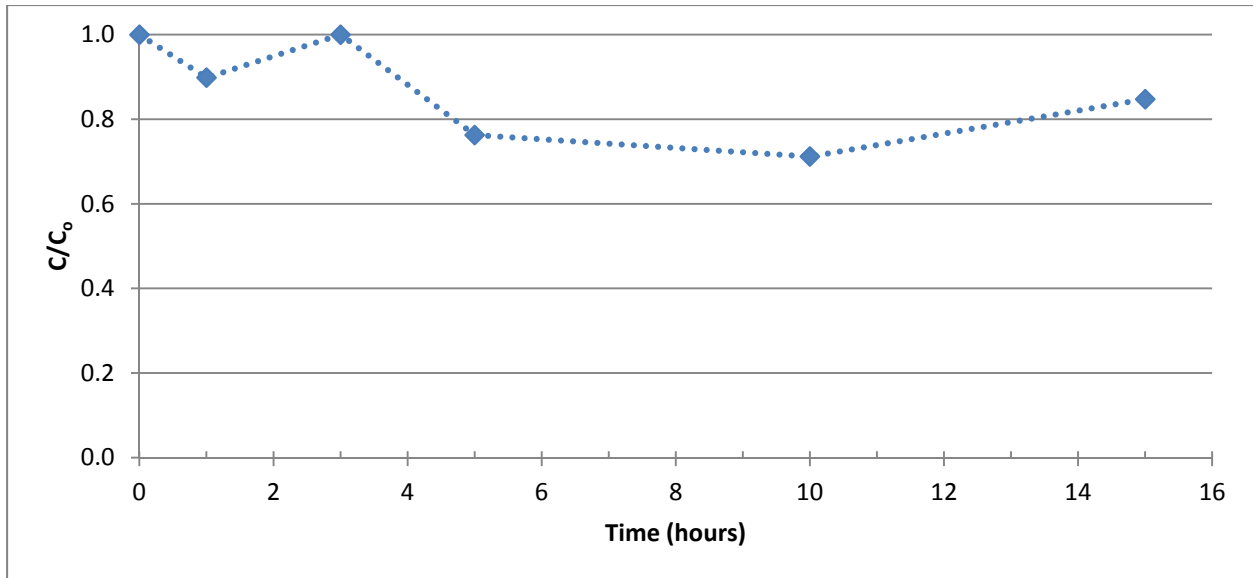


Figure 13. Calcium over time for the critical orifice advanced oxidation process post-treatment with 1" venturi (05/01/2015).

Critical Orifice Advanced Oxidation Process Post-Treatment with 3/4" Venturi

Since the size of the entrained oxygen bubbles was too large, it was decided to reduce the size of the venturi device to 3/4", and attempt a trial for COD removal over 15 minutes. However, no COD removal was observed (Figure 14).

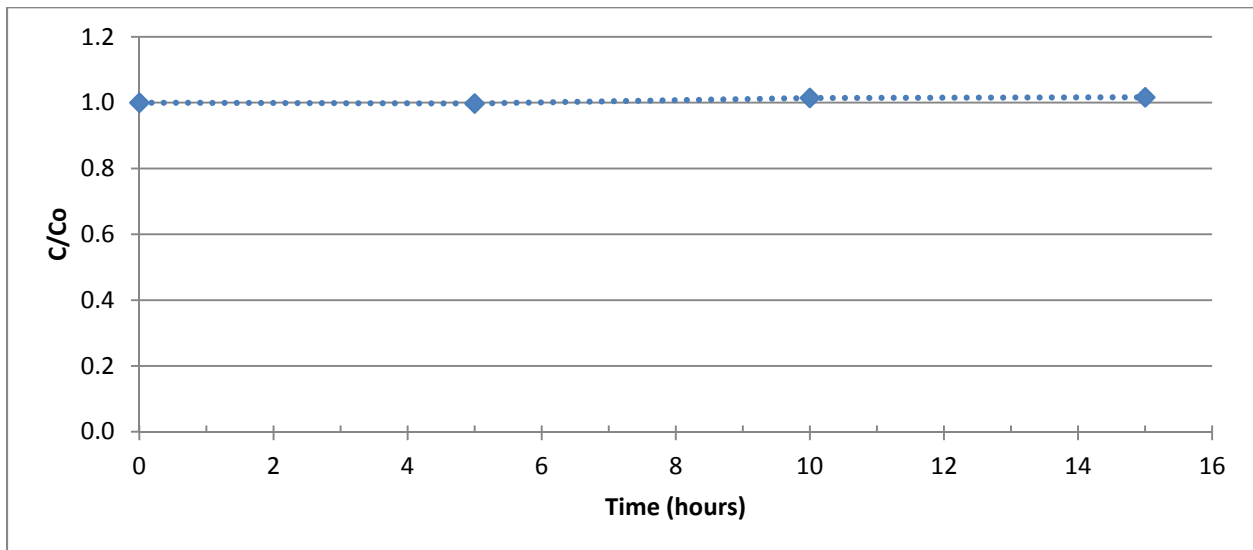


Figure 14. COD over time for the critical orifice advanced oxidation process post-treatment with 3/4" venturi (05/15/2015).

Research planned for the upcoming months:

- Complete the update to the literature review. The International Journal of Environmental Protection has invited our research group to submit a cover article on our work involving leachate treatment technologies.
- Meet with FDEP to discuss treatment targets for beneficial uses.
- Upcoming experiments will focus on pretreatment, post-treatment, and polishing steps involving the critical orifice unit in combination with the photocatalytic oxidation process.
- Another graduate student, Neil Coffman, is working on enhanced sedimentation and centrifugation techniques for separating the catalyst.

METRICS:

1. List graduate or postdoctoral researchers **funded** by **THIS** Hinkley Center project.

Last name, first name	Rank	Department	Professor	Institution
Lakner, Joseph	MSCE Candidate	CEGE	Meeroff	FAU
Coffman, Neil	BS/MSCE Candidate	CEGE	Meeroff	FAU

2. List undergraduate researchers working on **THIS** Hinkley Center project.

Last name, first name	Department	Professor	Institution
Walecki, Eve	CEGE	Meeroff	FAU
Dacey, Justin	CEGE	Meeroff	FAU

3. List research publications resulting from **THIS** Hinkley Center project.

Meeroff, D.E. and Lakner, J. (2015). “Safe Discharge of Landfill Leachate to the Environment.” Report to the Hinkley Center for Solid and Hazardous Waste Management, Report #1332027-A.

4. List research presentations resulting from **THIS** Hinkley Center project

TAG meeting presentations (May 27, 2014, January 30, 2015, March 26, 2015)
February 26, 2015 Engineering Week Graduate Student Poster Showcase, FAU.

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

None so far

6. How have the research results from **THIS** Hinkley Center project been leveraged to secure additional research funding?

Year two funding from the Hinkley Center for Solid and Hazardous Waste Management was secured. Additional funding is being pursued through the Solid Waste Authority of Palm Beach County and Waste Management. Owrang Kashef, a senior project manager from CH2MHill visited FAU from his office in Calgary, Canada to arrange a demonstration of our technology and to find a way to work together on future leachate treatment projects. Recently, a company called R3Fusion and a partner venture capital company, Beck Family Office, have entered into negotiations for an agreement with FAU and Dr. Meeroff to license technology and perform research/development activities at a larger scale.

7.. What new collaborations were initiated based on **THIS** Hinkley Center project?

F. Bloetscher, Ph.D., P.E., LEED AP, Craig K. Jones, Ph.D., Owrang Kashef, MBA, P.E., Roshan Jachuck, Ph.D., Ryan Beck, Esq., Ted Batkin

8/. How have the results from **THIS** Hinkley Center funded project been used by FDEP or other stakeholders?

To date, the results have not been used by stakeholders yet.

TAG members:

Mark Eyeington, Mark Maclean, Mark Bruner, Owrang Kashef, D.V. Reddy, Craig Ash, Ravi Kadambala, Ron Schultz, Jeff Roccapriore, André McBarnette, Dan Schauer, Damaris Lugo, Amanda Krupa, Richard Meyers, Amede Dimonnay, Art Torvela, Ted Batkin

TAG meetings:

January 30, 2015 (FAU)

March 26, 2015 (Private TAG meeting held at SWA)