QUARTERLY PROGRESS REPORT

March 1, 2016 to May 31, 2016

PROJECT TITLE: Multifunctional Energy- and Space-Saving Reactor for the Treatment of Landfill Leachate. Year II. Incorporation of Electrocoagulation

PRINCIPAL INVESTIGATOR(S): Gang Chen and Kamal Tawfiq

AFFILIATION: Department of Civil and Environmental Engineering, FAMU-FSU College of Engineering

COMPLETION DATE: March 1, 2016 to May 31, 2016

PROJECT WEBSITE ADDRESS (URL): http://www.eng.fsu.edu/~gchen (Multifunctional Reactor II)

EMAIL ADDRESS: gchen@eng.fsu.edu; tawfiq@eng.fsu.edu

PHONE NUMBER: 850-4106303

In this research, electrocoagulation is incorporated into the multifunctional energy- and space-saving reactor designed and tested in our prior research. Besides saving the chemical costs, the renovated reactor also has the capacity for arsenic and phosphorus removal. Limestone biofiltration is included to ensure the decomposition of residual organic contaminants.

Work Accomplished during This Reporting Period:

1. Experimental Design and Setup

Multiple anodic electrodes (arranged in parallel) were coupled with coagulation, flocculation and filtration in this research (Figure 1).

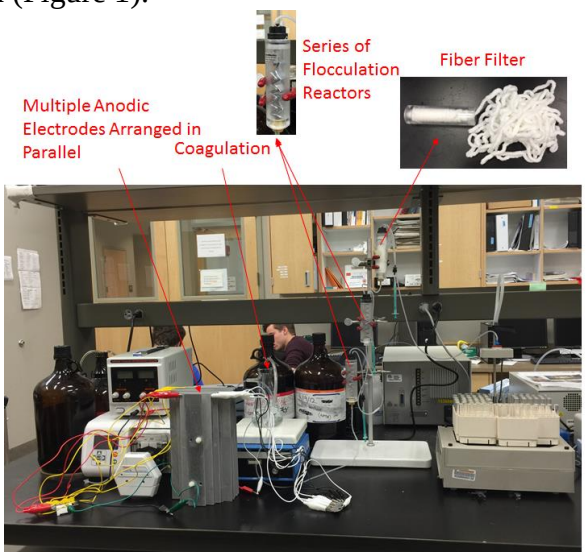

Figure 1. Experimental Setup of This Research

2. Experimental Results

The UV-vis spectrum variation of the Springhill Landfill leachate after electrocoagulation is illustrated in Figure 2. With the increase of electrocoagulation, the absorbance decreased accordingly. This is the indication that bigger particles are formed with the increase of electrocoagulation time.

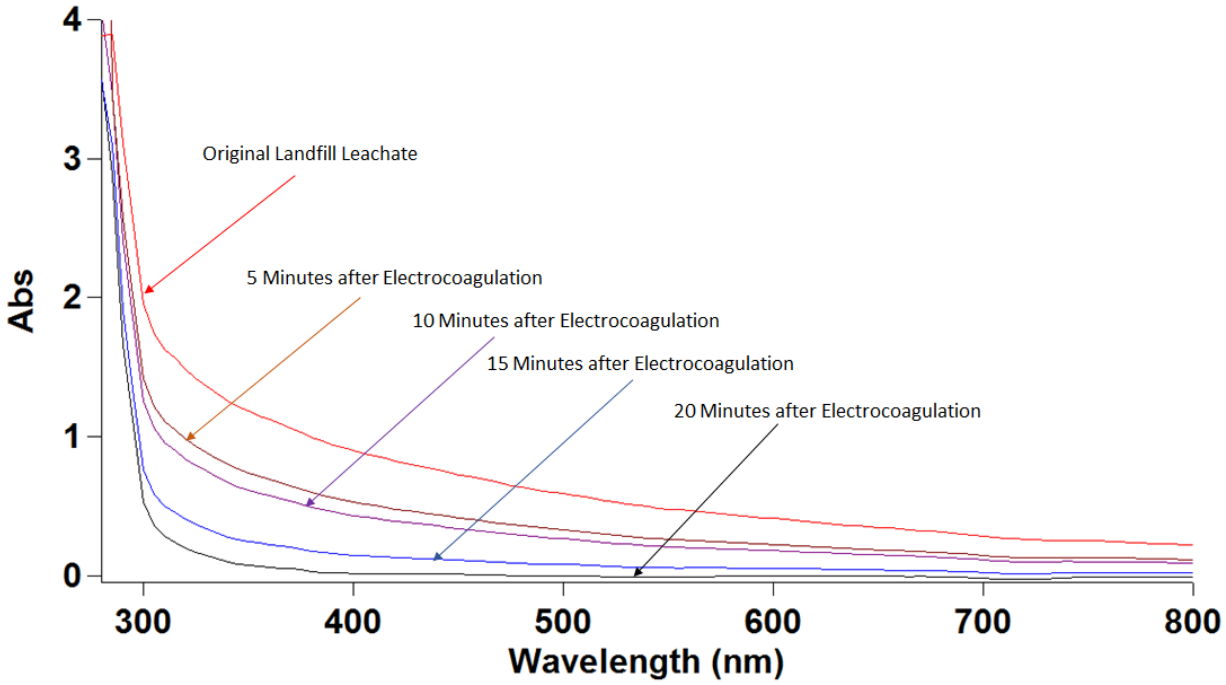

Figure 2. Leachate UV-Vis Spectrum after Electrocoagulation

Currently, elevated concentrations of arsenic have been detected in the leachate from lined landfills. In the leachate, As(V) and As(III) are the most commonly found arsenic species. Thermodynamic calculations and experimental results indicate that at high redox levels (pe + pH > 10), As(V) is the predominant arsenic species; while under moderately reduced conditions (pe + pH < 8), As(III) is the most abundant form of arsenic. As(V) adsorbs strongly to Al(III) and Fe(III) oxides. Studies show that 90% of arsenic can be associated with the iron fraction in the form of As(V).

In this research, arsenic removal was found to be strongly influenced by electrocoagulation and pH played a very important role for arsenic removal (Figure 3). In the leachate, inorganic arsenic occurred primarily as H_3AsO_4 at pH below 2, and both $H_2AsO_4^-$ and $HAsO_4^{2-}$ species existed in the pH range of 2 to 11. Based on the redox condition of our leachate sample, at pH higher than 9, As(V) started to dominate. With electrocoagulation, the released iron was subjected to hydrolysis. The subsequently formed iron hydroxide had strong adsorption for arsenate. Therefore, arsenic removal showed a sharp increase when pH was higher than 9. At low pH, however, As(III) was the dominating species. As(III) did not adsorb strongly to iron hydroxide. Subsequently, As(III) removal was not sensitive to pH (Figure 3).

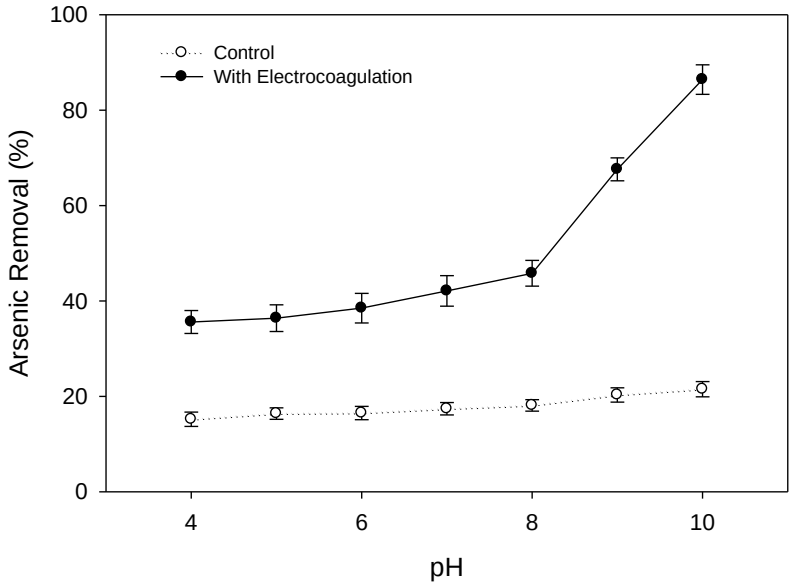

Figure 3. Arsenic Removal by Electrocoagulation as a Function of pH

Information Dissemination Activities:

Metrics:

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

Last name, first name	Rank	Department	Professor	Institution
Simeng Li	Ph.D.	Civil and Environmental Engineering	Gang Chen	Florida State University
Boya Wang	M.S./Ph.D.	Civil and Environmental Engineering	Gang Chen	Florida State University
Houzhen Wei	Postdoctoral Researcher	Civil and Environmental Engineering	Gang Chen	Florida State University

2. List undergraduate researchers working on this Hinkley Center project

Last name, first name	Department	Professor	Institution
Quinn Zacharias	Civil and Environmental Engineering	Gang Chen	Florida State University

3. List research publications resulting from this Hinkley Center project

Chen, G.*, P. Grasel, G. Millington, J. Hallas, H. Ahmad and K. Tawfiq, 2016, Chloride removal from landfill leachate by the ultra-high lime with aluminum process. Journal of Urban and Environmental Engineering, under review.

Li, S., Tawfiq, K. and Chen, G., 2016, Landfill Leachate Treatment by Electrocoagulation, Environmental Technology, to be submitted.

4. List research presentations resulting from this Hinkley Center project

Wang, B. and Chen, G. "Multifunctional Energy- and Space-Saving Reactor for the Treatment of Landfill Leachate". 101th Annual American Society of Microbiology Southeastern Branch Conference, Kennesaw, GA. Nov 13-15, 2015.

Chen, G., Wang, B. and Tawfiq, K. "Design and Testing of a Multifunctional Energy- and Space-Saving Reactor for the Treatment of Landfill Leachate", South Carolina Environmental Conference, Myrtle Beach, SC, March 14 to March 17, 2015.

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

Current research is in process and/or just published. Our prior research citation is as follows:

Power generation and nitrogen removal of landfill leachate using microbial fuel cell technology
By: Lee, Yongwoo; Martin, Lee; Grasel, Peter; et al.
ENVIRONMENTAL TECHNOLOGY Volume: 34 Issue: 19 Pages: 2727-2736
Published: OCT 1 2013
Times Cited: 11

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

"Electromagnetic Waves-Induced Heavy Metal Removal for Biosolids" by Gang Chen and Youneng Tang has been submitted to Environmental Research and Education Foundation in response to Environmental Research and Education Foundation Issues Targeted Request for Proposals: High Need Topics in Solid Waste Research.

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

We have initiated collaboration with John Hallas from Talquin Electric Cooperative, Inc. and Hafiz Ahmad from Florida State University at Panama City Campus from this research. In addition, we have been contacted by Jeffrey Cunningham from University of South Florida and requested for collaboration through an EPA-funded research center (http://usf-reclaim.org/). They are interested in investigating the removal and recovery of nutrients (nitrogen and phosphorus) at centralized wastewater treatment plants. They are currently conducting research on recovery and removal of N and P through a combination of engineered struvite precipitation and microbial fuel cells, which we have investigated through the projects sponsored by the Hinkley Center. They learned about our research

through our web sites and requested for collaboration. Other people involved in the collaboration include Daniel Yeh (USF), Treavor Boyer (UF), and Jim Mihelcic (USF).

8. How have the results from this Hinkley Center funded project been used (not will be used) by the FDEP or other stakeholders? (1 paragraph maximum).

We presented our research at Leon County Landfill and Springhill Regional Landfill. Leon County Solid Waste Management Director, Leon County Solid Waste Superintendent, District Manager of Waste Management at Springhill, Market Area Engineer of Waste Management, Inc. and Environmental Protection Manager of Waste Management, Inc., etc. attended the presentation. The technical achievement of this project was discussed and suggestions were provided for further research. We also shared the results with FDEP through TAG members of Owete Owete and Peter Grasel, who are in charge of groundwater modeling and monitoring and old landfills. In addition, we discussed the results with Talquin Electric Cooperative, Inc., which operates seven wastewater treatment plants.

TAG members: Peter Grasel, Owete Owete, John Hallas, Chen Lin, Hafiz Ahmad and Matthew Hendrix

TAG meetings: The first TAG meeting was held at FAMU-FSU College of Engineering on April 8, 2016. The second TAG meeting will be held at FAMU-FSU College of Engineering in September. The meeting minutes and presentation and discussion were available at www.eng.fsu.edu/~gchen (Multifunctional Reactor II).