QUARTERLY PROGRESS REPORT

December 1, 2015 to February 29, 2016

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

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

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Besides organic contaminants, nutrients, heavy metals and arsenic, high concentrations of chloride also become a concern of landfill leachate management in Florida. It is a great challenge to treat landfill leachate with high concentrations of these contaminants at the landfill sites. In our prior research, we designed a multifunctional energy- and space-saving reactor and tested the designed reactor for the treatment of landfill leachate with high ammonium, chloride and heavy metal contents. It has been demonstrated that this unique design provides an efficient and energy- and space-saving means of on-site management of landfill leachate. To further reduce the chemical costs and simplify the operation, electrocoagulation is to be incorporated into the multifunctional reactor in this research with further consideration of arsenic and phosphorus removal. In addition, limestone biofiltration is added 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). For this setup as shown in Figure 1, aluminum anodic electrodes were arranged in parallel. Subsequently, the electric current was divided between all the electrodes. A digital multimeter (Agilent, 34410A) was used to measure the operating current supplied by a DC power supply (HP, E3631A). The surfaces of aluminum anodes were first mechanically cleaned prior to experiments to remove any passive film that may have formed. After aluminum release from the electrodes, aluminum coagulant formed in the aqueous phase, which destabilized the contaminants in the landfill leachate. In the flocculation reactors, aggregation of the destabilized colloidal contaminants formed flocks, which can be then removed in the subsequent fiber filter.

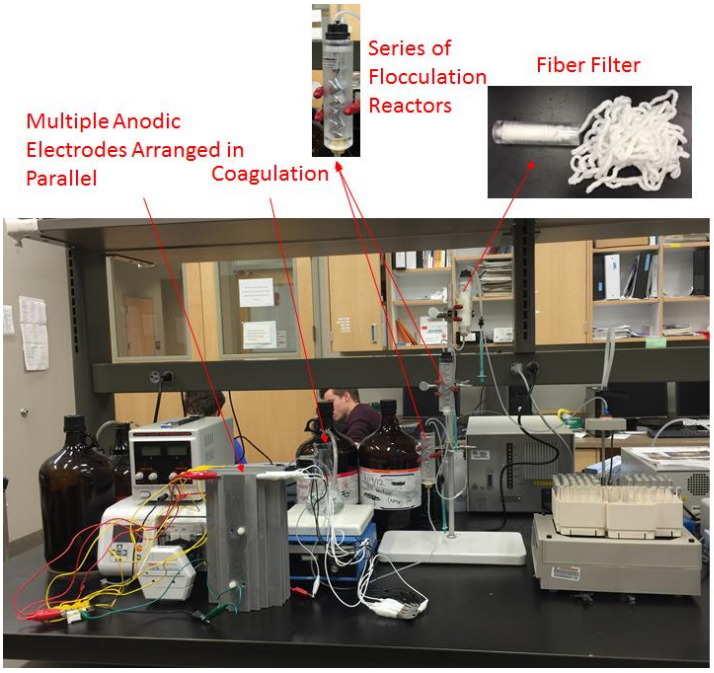


Figure 1. Experiment Setup of This Research

2. Experimental Results

The treatment performance of the system was first evaluated in terms of the electrical current (i.e., current density) and reaction time using landfill leachate collected from Springhill Landfill (Figure 2). High current density led to increased decomposition of the electrode material and enhanced coagulation and COD removal. Similarly, enhanced coagulation and COD removal were also observed for prolonged reaction time, i.e., COD removal increased with the increase of reaction time until 30 minutes, after which the increase became moderate.

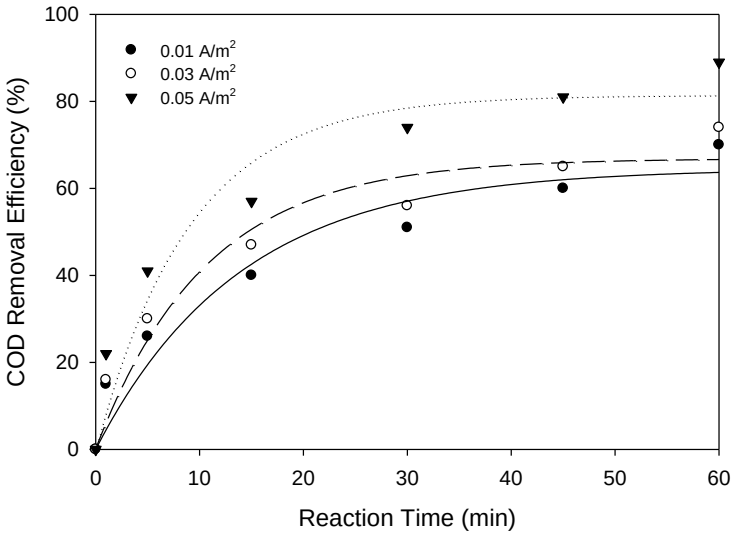


Figure 2. Current Intensity and Time on COD Removal

Since the quantity of electricity passed through was actually responsible for dissolution of metal ions at the electrodes, the relationship between current density and the quantity of the metal dissolved can be described by the Faraday's law:

$$W = \frac{i \times t \times M}{n \times F}$$ **Equation (1)**

where W is the amount of dissolved electrode (g/cm^2); i is the current density (A/cm^2); t is the electrocoagulation time (sec); M is the relative molar mass of the electrode (g); n is the number of electrons involved in the oxidation/reduction reaction (-); and F is the Faraday's constant (96,500 C/mol). The aluminum release was thus calculated, which linearly increased with the increase of reaction time (Figure 3). Subsequently, there was a trend that COD removal increased with the increase of released aluminum (Figure 4).

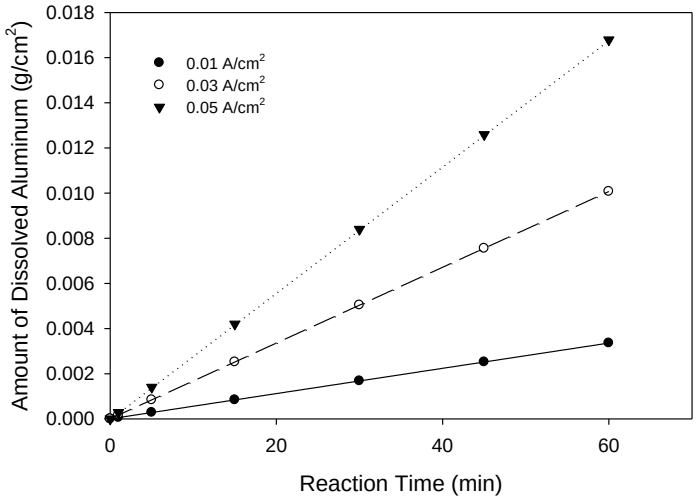


Figure 3. Current Intensity and Time on Aluminum Dissolution

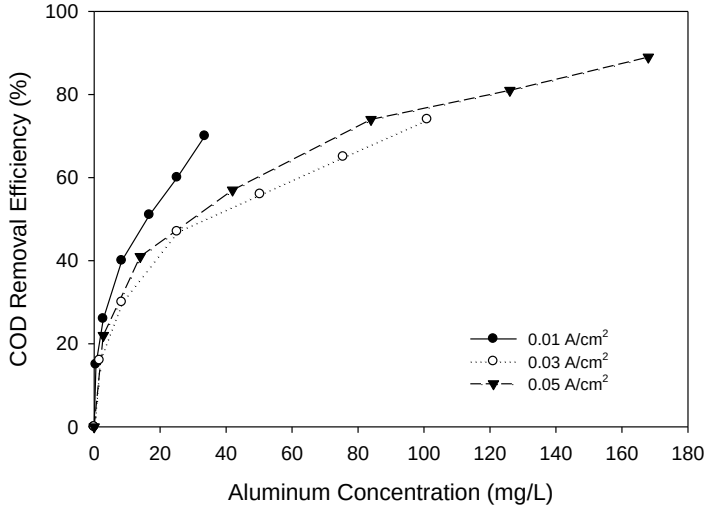


Figure 4. COD Removal as a Function of Released Aluminum

Figure 1. Process Flow Diagram – Mine Water Pilot

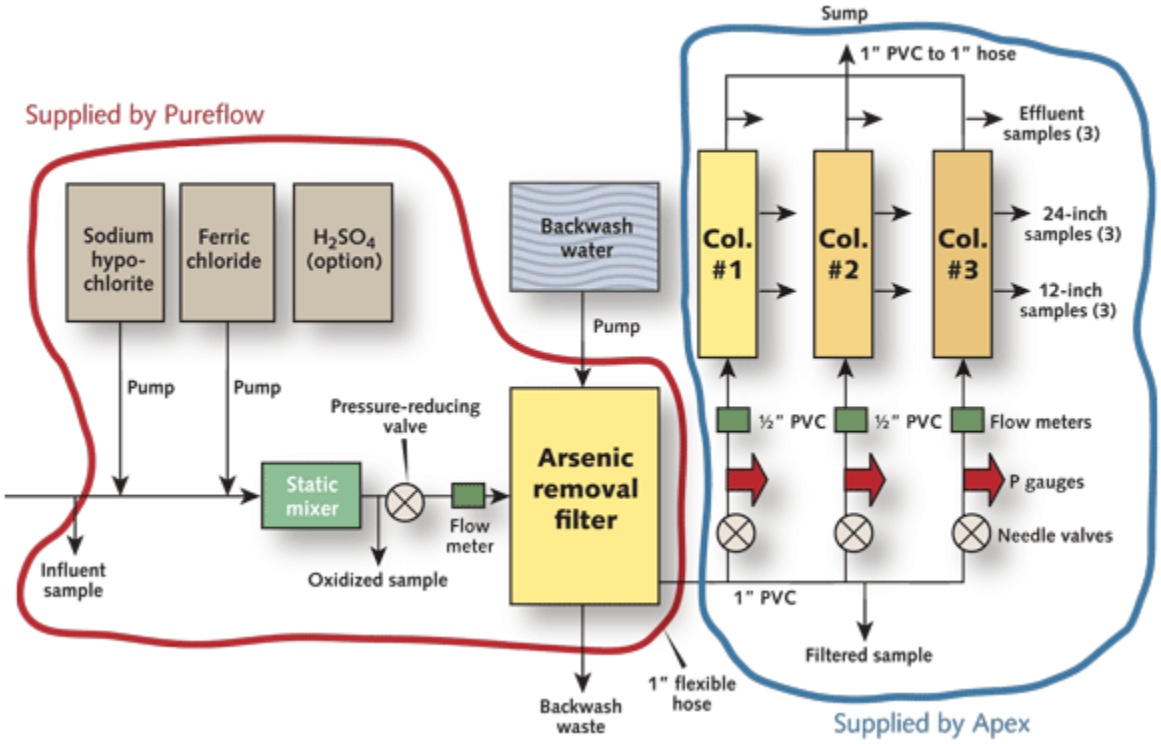
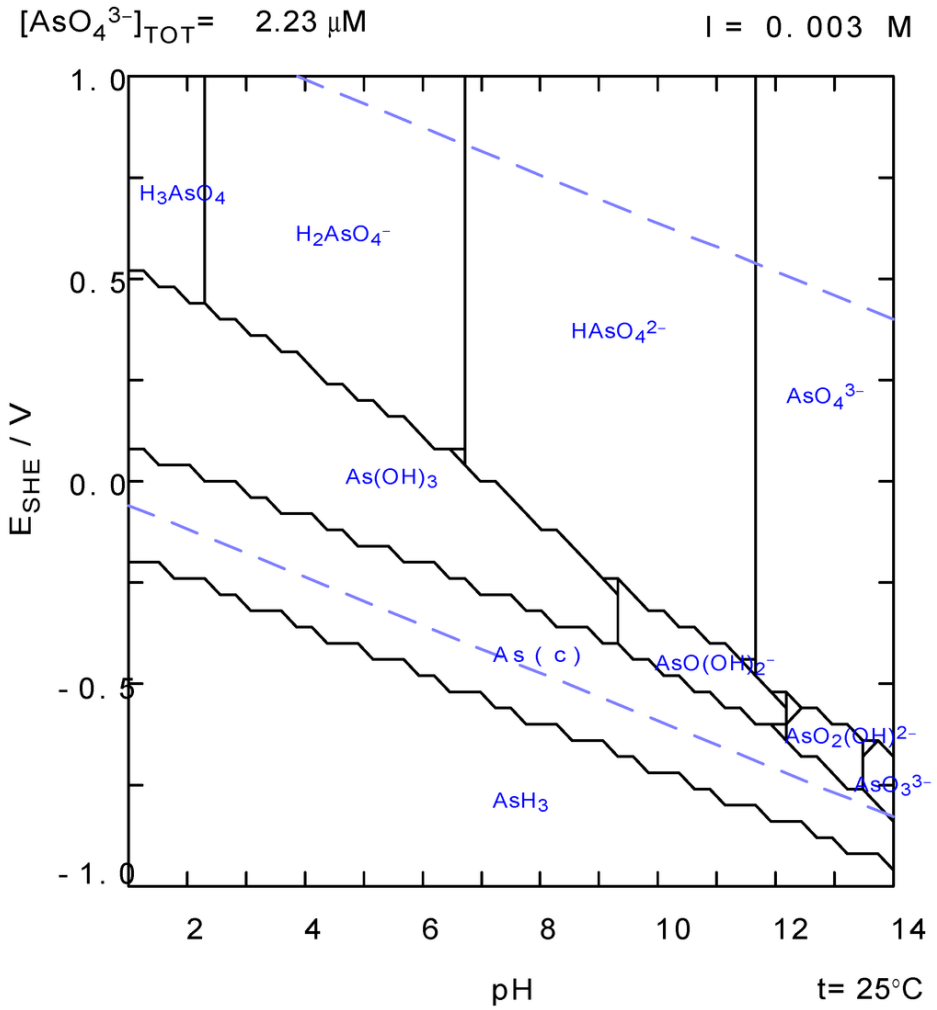


Table IV Characteristics of waste waters under biological treatment (maximum and minimum values).

Parameter	Wastewater	Settled water	Treated water
E_H(in V)	-0.014 / -0.508	-0.150 / -0.510	-0.023 / -0.158
rH	11.0 / -2.8	10.4 / -3.0	15.0 / 9.9
pH	7.05 / 7.82	7.01 / 7.70	7.57 / 8.18
O_2 (% saturation)	7 / 0	10 / 0	120 / 31
COD (mg/l)*	651 / 961	359 / 610	88 /154
BOD_5 (mg/l)**	250 / 470	170 / 346	13 / 88
NH_3 (mg/l)	24 / 40	23 / 36	14 / 32

*Chemical oxygen demand to $K_2Cr_2O_7$.
**Biochemical oxygen demand: five days, 25 °C, darkness.


[AsO4 3-]TOT= 2.23 µM
I = 0.003 M
1.0
0.5
0.0
-0.5
-1.0
ESHE / V
H3AsO4
H2AsO4-
HAsO4 2-
AsO4 3-
As(OH)3
As(c)
AsO(OH)2-
AsO2(OH)2-
AsO3 3-
AsH3
2
4
6
8
10
12
14
pH
t= 25°C

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.	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: 8 (from Web of Science Core Collection)

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 will be 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 Gary Millington, FDEP Subsection Manager and Peter Grasel, who is in charge of ground water 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, Gary Millington, John Hallas, Chen Lin, Hafiz Ahmad and Matthew Hendrix

TAG meetings: Information of this project is available through http://www.eng.fsu.edu/~gchen (Multifunctional Reactor II). The first TAG meeting will be scheduled between late March and early April 2016 at FAMU-FSU College of Engineering.