QUARTERLY PROGRESS REPORT

January 1, 2017 to March 31, 2017

PROJECT TITLE: Electromagnetic Wave-Induced Heavy Metal Removal for Dewatered Biosolids Composting

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COMPLETION DATE: January 1, 2017 to March 31, 2017

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Heavy metal contents in dewatered biosolids prevent the nutrient-rich organic materials from being used in composting. Variable chemical extraction methods have been investigated for heavy metal extraction from biosolids and the results are not very satisfactory owing to the high costs as well as the potential environmental impact. Electromagnetic wave (EW)-induced heavy metal removal offers a sound solution for this problem. In this research, we use EW with low-MHz frequencies that have much deeper depth impact on biosolids (i.e., penetration depths) to stimulate heavy metal release from biosolids. Under EM conditions, composting of biosolids with yard trash is investigated. Due to their alternating natures, EM waves do not alter reactions (e.g., oxidation). Therefore, EM treatment does not interfere with the microbial activities.

Work Accomplished during This Reporting Period:
Heavy Metal Quantification and Removal from Sewage Sludge
Two types of sludge were collected form Thomas P. Smith Water Reclamation Facility (TPS) located in Tallahassee, Florida. One was the sludge cake from dewatered sludge of anaerobic digestion; the other one was the granular sludge pellet that was produced by the thermo-treatment of the sludge cake.

Three heavy metals nickel, zinc, and copper were extracted from granular sludge pellet and quantified by the Aqua Regia Digestion Method. The digestion was performed in 125 ml glass beakers. The Aqua Regia used in this experiment was produced by mixing concentrated hypochlorite acid (37% v/v) with concentrated nitric acid (70% v/v) at a molar ratio 3:1. 0.5 gram of the sludge was digested with 12.5 ml Aqua Regia at 110℃ for 3 hours. After digestion, cooling down to the room temperature and filtration with Whatman # 42 Filter Paper, the filtrate was collected diluted to 100 ml with deionized water. The heavy metal concentrations in the

diluted filtrated was measured by Microwave Plasma-Atomic Emission (Agilent Technologies 4100 MP-AES) as reported in Table 1.

Table 1. Heavy Metal Content in Granular Sludge Pellet

Heavy Metal Species	Cu	Zn	Ni
Content (mg/kg)	493.33	716.67	Not Detectable

Three conventional chemical heavy metal removal methods were conducted for heavy metal extraction. The reagents and extraction conditions are summarized in Table 2.

Table 2. Heavy Metal Extraction Reagents and Conditions

Methods	Reagent	Conc.	Dosage	S/L Ratio	Contact Time
Inorganic Acid	Sulfuric Acid	20% (v/v)	10 ml	1/20	24 hours
Organic Acid	Acetic Acid	20% (v/v)	10 ml	1/20	24 hours
Chelating	EDTA	0.05 M	10 ml	1/20	24 hours
Control	DI Water	NA	10 ml	1/20	24 hours

After mixing with the reagents, the samples were put on the rotator (Glas-Col, Rugged Rotator) for shaking of 24 hours, after which, the samples were centrifuged (VWR Horizontal Centrifuge) at 3100 rpm for 20 minutes. The supernatants were collected, diluted, and measured for heavy metals by the Microwave Plasma-Atomic Emission (Agilent Technologies 4100 MP-AES). Triplicate experiments were conducted for each method and the average results are presented in Figure 1.

Sulfuric acid had the best heavy metal extraction results, followed by acetic acid and EDTA. The advantage of heavy metal extraction by sulfuric acid was significantly pronounced for Cu. The extraction results by EDTA was not as good as those of the acids. The reason is that iron, which is commonly found in the sludge, has priority to be chelated with EDTA, which interferes with the chelation of EDTA with other heavy metals.

Work of Next Steps:

Reactor Setup and Parameter Characterization

The reactor for this experiment will be set up, which will consist of an acrylic box with a dimension of 40 cm × 40 cm × 50cm. Inside the reactor, there is a 38 cm × 38 cm × 48 cm radio-frequency (RF) resonant cavity (Figure 2). The cavity structure will be built using copper mesh screens to enable imaging and visualization. The opening diameter of the copper mesh is ~ 3 mm (1/8 inch), which is much smaller than the wavelength of the applied 50-200MHz frequency waves (160 mm ~ 660 mm). The inner conductor passes through a brass piece soldered to the top copper boundary, hence, sharing the same electric ground as the outer conductor to provide electrical continuity to the resonant cavity. The electromagnetic field will be generated using a function generator (Agilent E4400B) with an amplifier (Amplifier Research 100LMB). The resonant cavity will be electromagnetically excited via the loop antenna connected to the electromagnetic source.

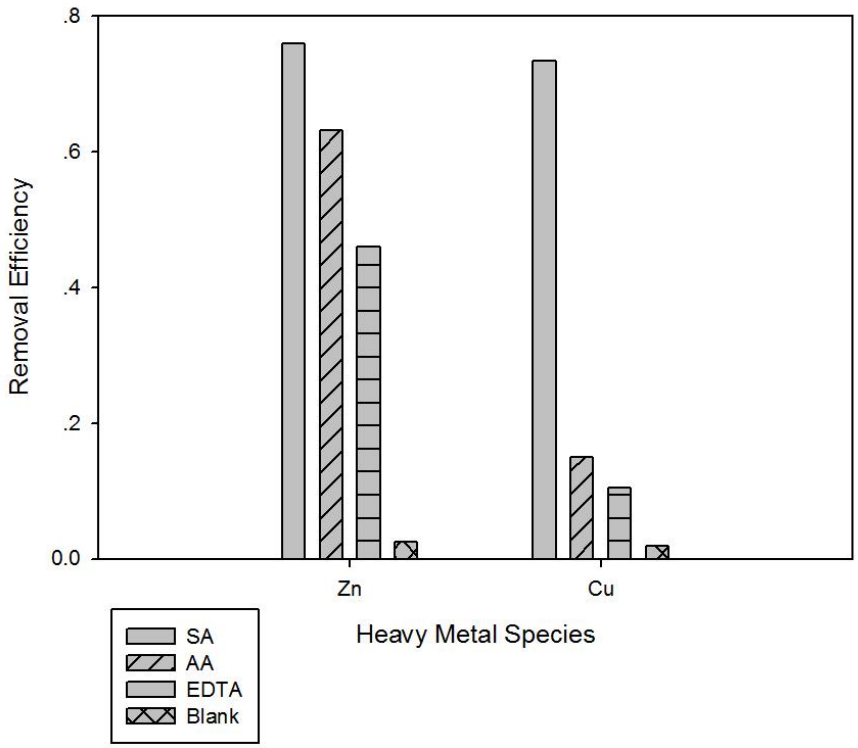

Figure 1. Cu and Zn Extraction from Granular Sludge Pellet
SA: Sulfuric Acid, AA: Acetic Acid

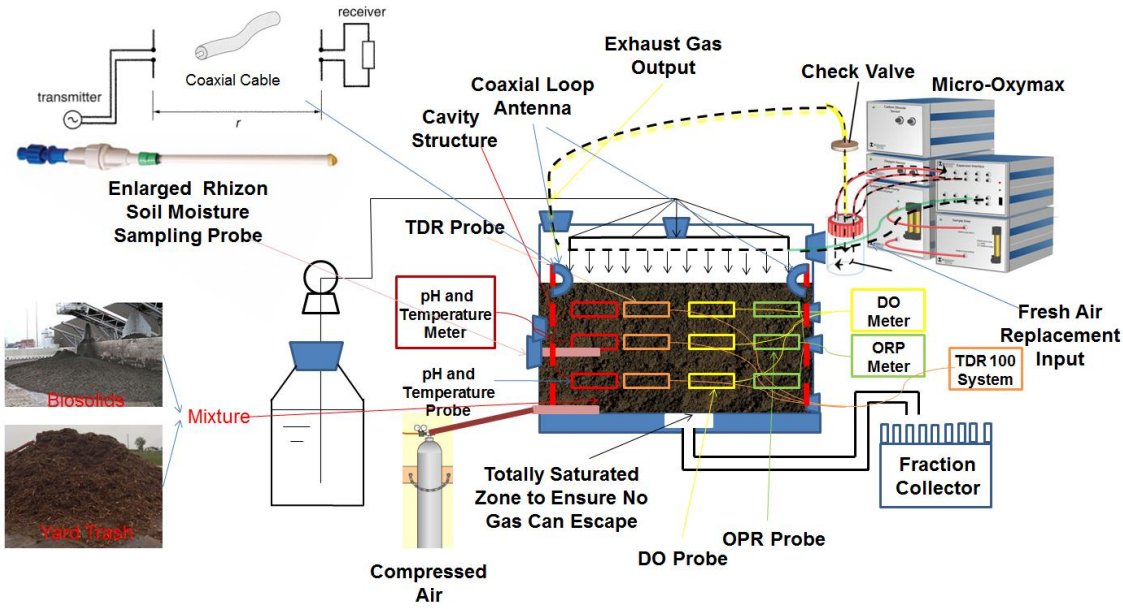

Figure 2. Experimental Reactor Setup

Information Dissemination Activities:

Metrics:

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

Last name, first name	Rank	Department	Professor	Institution
Runwei Li	Ph.D.	Civil and Environmental Engineering	Gang Chen	Florida State University
Hongying Yuan	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
Kadeem Rowe	Civil and Environmental Engineering	Gang Chen	Florida State University

3. List research publications resulting from this Hinkley Center project
Li, R., Tang, Y., Tawfiq, K. and Chen, G., 2017, Electromagnetic Wave-Induced Heavy Metal Removal for Dewatered Biosolids Composting, Environmental Technology, in preparation.

4. List research presentations resulting from this Hinkley Center project
Li, R., Tang, Y., Tawfiq, K. and Chen, G. "Electromagnetic Wave-Induced Heavy Metal Removal for Dewatered Biosolids Composting". 103th Annual American Society of Microbiology Southeastern Branch Conference, Nov., 2017.

5. List who has referenced or cited your publications from this project?
Current research is in process. Our prior research on composted sewage sludge that was published in 2007 has been cited 115 times:

Cheng, H., W. Xu, J. Liu, Q. Zhao, Y. He and G. Chen, 2007, Application of composed sewage sludge (CSS) as a soil amendment for turfgrass growth. Ecological. Eng., 29, 96-104.
Cited by 115

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/). We are now working with Dr. Sarina J. Ergas on nutrient management in solid waste.

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 keep close contact with managers of Leon County Landfill, Springhill Regional Landfill (Jackson County) and Perdido Landfill (Escambia County). In addition, we work closely with Thomas P. Smith Water Reclamation Facility located in Tallahassee, FL. We discuss the technical achievement of this project with the managers and request for suggestions to further our research. We also share the results with FDEP through TAG members of Joe Dertien and Owete Owete. We also discuss the results with Talquin Electric Cooperative, Inc., which operates seven wastewater treatment plants.

Tag Members: Joe Dertien, Owete Owete, John Hallas, Chen Lin, Hafiz Ahmad, and Matthew Hendrix

TAG meetings: Information of this project is available through http://www.eng.famu.fsu.edu/~gchen/index_files/Page570.htm. The first TAG meeting has been scheduled on May 4 at FAMU-FSU College of Engineering.