Project 3: Generation of Renewable Energy from Food Waste

Area Coordinator:
Dr. Drew C. McAvoy
Adjunct Professor of Environmental Engineering
Department of Biomedical, Chemical, and Environmental Engineering
College of Engineering and Applied science
PO Box 210012, University of Cincinnati
Office: 740 Engineering Research Center
E-mail: drew.mcavoy@uc.edu
Phone: 513-556-3952

Sub-Area Coordinator:
Dr. Pablo Campo-Moreno
Assistant Research Professor of Environmental Engineering
Department of Biomedical, Chemical, and Environmental Engineering
College of Engineering and Applied science
PO Box 210012, University of Cincinnati
Office: 766 Engineering Research Center
E-mail: campomp@ucmail.uc.edu
Phone: 513-556-3637

Graduate Research Assistant:
Mr. Narasimman Lakshminarasimman Meanakshisekar (LM)
M.S. Student, Environmental Engineering
Office: 750 Engineering Research Center
E-Mail: lakshmnn@mail.uc.edu
Phone: 513-652-4884 (C)

Project Summary

The USEPA estimates that approximately 36 million tons of food waste is generated in the U.S. each year with a majority of it ending up in landfills (>97%). Moreover, the United Nations Food and Agriculture Organization reports that food waste in landfills is the third largest emitter of greenhouse gases worldwide. In order to reduce greenhouse gas emissions from food waste, alternatives to landfilling are desperately needed. One alternative that could significantly reduce greenhouse gas emissions and also produce renewable energy is the anaerobic digestion of food waste. Advantages of this approach are that it: (1) provides a source of methane that could be used as a replacement for natural gas that is currently being obtained from hydrofracking and (2) reduces the effects of climate change by utilizing huge amounts of methane that would otherwise be released into the atmosphere from landfills (where methane is 25 times more potent than carbon dioxide as a global warming gas). Another advantage is that this process produces a digestate byproduct that can be used as low cost organic soil fertilizer.

The project goal is to help the teachers gain a hands-on experience in understanding the operation and fundamental process of an anaerobic digester. Anaerobic digestion is a biochemical process in which different types of heterotrophic anaerobic bacteria work together to degrade complex organic molecules in the absence of oxygen. This process converts organic substrate to biogas by going through the following steps: (1) hydrolysis – breakdown of particulate organic matter into simple macro molecules, (2) fermentation – conversion of organic macromolecules into long chain volatile fatty acids (VFA), (3) acetogenesis – formation of acetic acid from the long chain VFAs, and (4) methanogenesis – production of methane (CH_4) and carbon dioxide (CO_2) from acetic acid by action of methanogenic bacteria. Food waste is an excellent substrate for anaerobic digestion. This project will look at key parameters that affect the conversion of food waste into biogas.

The teachers who select this project will conduct anaerobic digestion experiments to address the key factors that affect biogas production. Moisture content will be investigated because it can affect the transfer of VFAs to the methanogens, which may increase the gas production (Nagao et al., 2012). The digestate to food waste recycle ratio will also be assessed to optimize the process for gas production. Because it is not known what effect co-digestion of food waste with other organic wastes will have on gas production, the co-digestion of food waste with animal manure and wastewater treatment plant digester sludge will also be investigated.

Table 1. Experimental Plan

Experiment	Reactor	Condition
1	1	Moisture effect – same moisture content as pilot reactor (control)
1	2	Moisture effect – increase moisture content by 10% above pilot reactor
1	3	Moisture effect – increase moisture content by 20% above pilot reactor
1	4	Organic loading effect – increase ratio of food waste to digestate
1	5	Organic loading effect – decrease ratio of food waste to digestate
2	1	Co-digestion – same conditions as pilot reactor (control)
2	2	Co-digestion – amend with equal amounts of animal manure to food waste
2	3	Co-digestion – amend with half the amount of animal manure to food waste
2	4	Co-digestion – amend with equal amounts of wastewater digester sludge to food waste
2	5	Co-digestion – amend with half the amount of animal manure to food waste

A suggested experimental plan is provided in **Table 1**. Each experiment will take about two weeks to perform, with additional time required for reactor preparation, sample analysis, and data interpretation. Briefly, food waste will be collected from a dining hall at UC and brought to the Environmental Control Chamber where it will be shredded to the desired particle size. The shredded waste will then be mixed with digestate from a pilot-scale anaerobic digester depending on the conditions laid out in the experimental plan (**Table 1**) and placed in 3-L reactor test vessel for test initiation (**Figure 1**). The digestate, which is rich in heterotrophic anaerobic bacteria, will serve as an inoculum for the fresh food waste. Samples from the 3-L reactors will be analyzed for pH, alkalinity, volatile solids, volatile fatty acids, ammonia, and carbon and nitrogen content using Standard Methods at the beginning and end of the experiments. In addition, gas production will be monitored during the experiments using the water displacement method and gas composition (CH_4 and CO_2) will be analyzed by gas chromatography/mass spectrometry (**Figure 2**). In addition, a field trip will be arranged to visit a local WWTP that utilizes anaerobic digestion in their treatment process. This trip is expected to provide a real-world experience on the use of anaerobic digestion in treating organic wastes.

Figure 1: Reactor Test Vessel

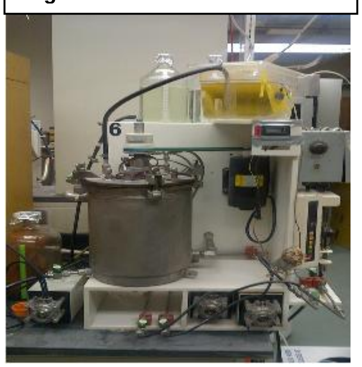
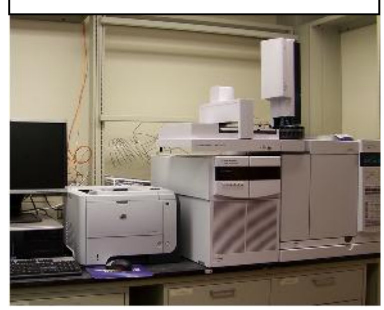


Figure 2: GC/MS Analysis



Expected outcomes

It is expected that by the end of the RET summer program the teachers will have a thorough knowledge of: (1) the biological principles behind the anaerobic digestion process, (2) the major factors that affect anaerobic digestion performance, (3) the analytical methods needed to test digester characteristics, and (4) the background on how to set up a laboratory-scale anaerobic digester. This knowledge can then be taken back to the classroom for implementation. This research will help increase the teachers' awareness of relating math and science knowledge to a real-world societal problem of food waste disposal.

Possible Ideas for Classroom Implementation

The teachers could use the knowledge gained in this research as a basis for developing a classroom implementation unit in science and/or math. For example, a bench-scale anaerobic digester could be set up in a science laboratory to investigate the conversion of food waste to biogas. Food waste from the school cafeteria could be used in these experiments. Performance of the anaerobic digestion reactors could then be assessed by measuring basic parameters like pH, alkalinity, moisture content, and gas production. For the math classroom, graphical analysis, rate computations, curve fitting, and error analysis could be performed using the data obtained from the anaerobic digestion experiment. The AC/SAC and/or GRA could also visit the teachers' classroom to provide additional training to the students in experimental design and data analysis. For further insight into anaerobic digestion process, teachers and their students could tour the laboratories at UC and/or an anaerobic digester at a local wastewater treatment plant.

References

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