Huntsman Environmental Research Center

BIENNIAL REPORT 2012-2013

PROJECTS AND PRODUCTS

Summary. During the years 2012-2013, HERC themes included biodegradation, air quality, recycling, and conservation of trees. HERC teamed up with the Institute of Biological Engineering, the Algae Biomass Organization, Silver Eagle Petroleum, Produced Water companies, and WesTech-Inc. engineers to accomplish projects included biodegradation of organic chemicals in wastewaters under aerobic and anaerobic conditions for the fermentation or production of value products for industry, including acetone, butanol, and ethanol. The Engineering Education Department developed curriculum materials for the course Computer Engineering Drafting for green energy and environmental systems in collaboration with the Utah On-Site Wastewater Treatment Program. The Utah On-Site Wastewater Treatment Training Program offered several workshops to assist all 20 counties and the 12 local health departments in Utah with certification.

2013

Project: Anaerobic Treatment of Wastewater for the Production of High Value Bioproducts

HERC Theme: Biodegradation

Collaborators: Logan City Environmental Department, WesTech-Inc. Engineering, Silver Eagle Petroleum (Utah)

Students Supported: Joshua Ellis (PhD), Neal Hengge (BS)

Results/Products/Outcomes: Developing renewable sources of energy is gaining interest due to limited supplies, rising costs, and environmental impacts of exploiting fossil fuels. Biosolvents such as acetone, butanol, and ethanol are attractive sources of fuel which can aid in replacing our dependence on foreign oil. Butanol is of particular interest due to its ability to directly replace gasoline, thus considered a drop-in-fuel. Microalgae were utilized for the production of acetone, butanol, and ethanol using the anaerobic microbe Clostridium saccharoperbutylacetonicum. The microbe was present in anaerobic lagoon sediments from a wastewater treatment facility in Utah. Lagoons are commonly utilized throughout rural and developing countries for the stabilization of municipal, industrial, and agricultural organic waste. This technology platform was also utilized to study the microbial diversity of a municipal waste bioremediating community. Integrating fundamental science with engineering strategies was demonstrated.

Dissemination of Results: Presentation. Isolation and characterization of anaerobic microorganisms from the Logan City Wastewater Lagoon System for the production of high value bioproducts. 2013. National Conference of the Institute of Biological Engineering, Raleigh. NC, March 7-9. Joshua T. Ellis, Neal Hengge, Ronald C. Sims, and Charles D. Miller

	Bioproduct yield from anaerobic treatment
Butanol (gm)	0.173
Acetone (gm)	0.058
Total ABE (gm)	0.257

(gm) = grams of bioproduct produced per gram of microorganism isolated from lagoon sediments

Project: Production of Bioplastic Materials from Wastewater using Genetically Engineered *E. coli*

HERC Theme: Biodegradation, Recycling

Collaborators: NASA, Algae Biomass Organization (AB)), Institute of Biological Engineering

Students Supported: Asif Rahman (PhD)

Results/Products/Outcomes: Currently, there is a need to reduce dependence on petroleum-derived commodities and a move towards renewable products. Bioplastic materials, referred to as Polyhydroxybutyrate (PHBs) are a group of biodegradable plastics that are produced by a wide variety of microorganisms. Bioplastic materials produced in this project were of interest to the NASA regarding the "Mission to Mars." Asif Rahman was subsequently offered a positon at NASA at Ames Center, California. Bioplastic materials were produced by genetically engineered bacteria (*E. coli*) using food sources (carbon) in wastewater to lower the costs associated with the food source for bacterial manufacturing of bioplastic materials.

Dissemination of Results: Presentation. Economic production of Polyhydroxyalkanoates in Escherichia coli. 2013. National Conference of the Institute of Biological Engineering, Raleigh. NC, March 7-9. Asif Rahman, Ronald C. Sims, Randolph Lewis, and Charles D. Miller

Production of bioplastic material from the bacterium *E.coli* with wastewater derived algae

Algae Media	Bioplastic (%) Yield	Bioplastic (gm/ liter) Concentration
1%	31	2.30
2%	28	2.09
10%	4.6	0.32
1.5% sugar	47	5.43

Results indicated the successful production of bioplastic using algae cultivated on wastewater.

Project: Rotating Algae Biofilm Reactor Treats Oil and Gas Extraction (Produced) Water

HERC Theme: Air Quality, Recycling (nutrients), biodegrradation

Collaborators: LaPoint Recycling (Uintah Basin), Integrated Water Management (Uintah Basin)

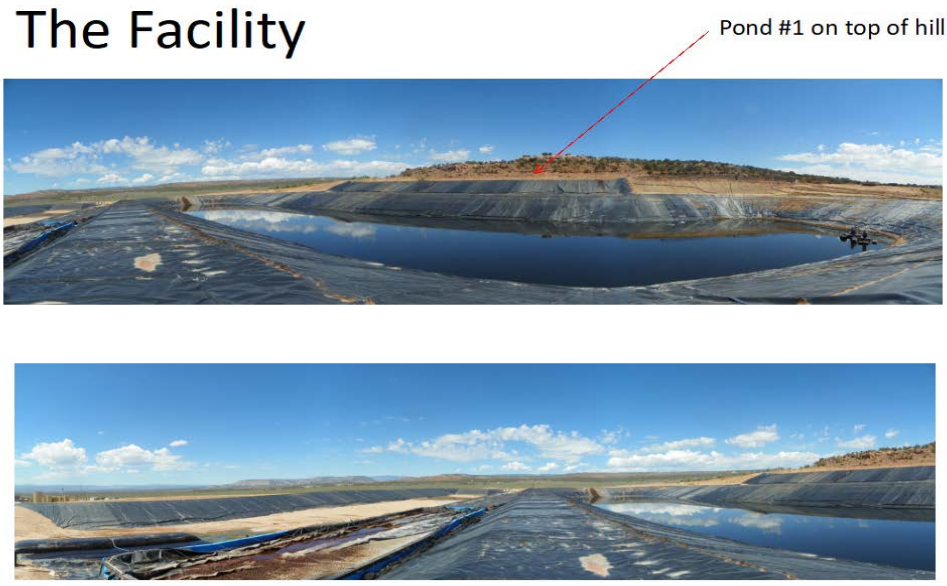
Students Supported: Jonathan Wood (MS), Cody Maxfield (BS), Tyler Gladwin (BS)

Results/Products/Outcomes: Industry waste in the form of Produced Water containing high concentrations of salts and nutrients, including nitrogen and phosphorus, was demonstrated to support the growth of microalgae that was naturally occurring in the Logan City Wastewater Treatment Plant. This project was a collaboration with two Utah companies (LaPoint and Integrated Water Management) that have large quantities of wastewater from oil and natural gas extraction that are not currently reused or recycled, but either reinjected into the subsurface or disposed to evaporation ponds in the Uintah Basin area of Utah. The evaporation of Produced Water chemicals contributes to the poor air quality in the Uintah Basin. This project tested the ability of algae and associated bacteria to grow on Produced Water and thereby help improve air quality through biodegradation of volatile organic chemicals that escape into the atmosphere when untreated.

The video shows the biofilm, composted of algae and bacteria, on a rotating drum (Rotating Algae Biofilm Reactor) being harvested by student Jonathan Wood, who was supported on the project. LaPoint and Integrated Water management provided the Produced Water, assistance in obtaining samples, in-kind support from their staff for the project.

Produced Water from oil and natural gas extraction is treated using microalgae and associated bacteria on a Rotating Algae Biofilm Reactor (Student Jonathan Wood is harvesting the biofilm cultivated).

Floating Rotating Algae Biofilm Reactors (RABRs) designed for implementing in ponds and lagoons with industry wastewater and municipal wastewater.



Integrated Water Management Site in Utah's Uintah Basin

Dissemination of Results:

1. Cyanobacterial Biofilms Cultured in Oilfield Wastewater (Produced Water). 2013. Institute of Biological Engineering National Conference. Poster Presentation. Raleigh, NC, March 7-9. Jonathan Wood, Dong Chen, Jon Takemoto, Ronald C. Sims
2. Rotating Algae Biofilm Reactor for Wastewater Remediation and Bioproducts Production. 2013. Seventh Annual Algae Biomass Organization Summit. Orlando, FL. Jonathan Wood, Ashik Sathish, Dong Chen, Jon Takemoto, and Ronald C. Sim

2012

Project: Analysis of a Biofuel (Methane) Producing Microbial Community Within an Algae Fed Anaerobic Digester

HERC Theme: Biodegradation

Collaborators: WesTech Engineering, Algae Biomass Organization (ABO), Institute of Biological Engineering, Silver Eagle Refining

Students Supported: Joshua Ellis (PhD), Cody Tramp (MS), Neal Hengge (BS)

Results/Products/Outcomes: Lagoons are commonly utilized throughout rural and developing countries for the stabilization of municipal, industrial, and agricultural organic waste. For this project, we measured the microbial diversity from the Logan City (Utah) Wastewater Treatment System from both oxic and anoxic communities using pyrosequencing technology. Output data provided 47,025 sequences. Study of these communities showed Cyanobacteria, Chlorophyta, and Proteobacteria to be dominant in the wastewater above the sediments where oxygen concentration were positive, whereas Euryarchaeota and Firmicutes were most dominant in the anaerobic sediments on the lagoon bottom. The wastewater and anaerobic sediments had a total of 339 unique genera, with 224 found in the aerobic fraction and 115 of were discovered in the anaerobic sediments. These data exhibit a great deal of diversity, and depicted organisms that are vital for biodegrading municipal waste. Understanding the microbial system within wastewater treatment plants is crucial for optimizing biodegradation, particularly as regulations become stricter.

Dissemination of Results: Metagenomic Analysis of a methanogenic community within an algae fed anaerobic digester. 2012. Presentation and First Place Award. National Conference of the Institute of Biological Engineering, Indianapolis, IN, March 1-3. Josh Ellis, Cody Tramp, Neal Hengge, Ronald C. Sims, and Charles D. Miller

Anaerobic digester at the Logan City Wastewater Treatment Plant used for testing, characterization, and analysis. The digester was provided by Logan City.

Project: Filtration of Algae for Harvesting from Municipal Wastewater Lagoons

HERC Theme: Recycling (nutrients), Air Quality (Greenhouse Gases control)

Collaborators: Pall Corporation, Pittsburgh, PA; Carollo Engineering; WesTech Engineering; Logan City Environmental Department; Algae Biomass Organization (ABO)

Students Supported: Misheka Wilson (MS), Zak Fica (BS), Alexa Lunt (BS), Daniel Dye (PhD)

Results/Products/Outcomes: The technology of cross flow filtration (CFF) was proposed as a chemical-free form of algae harvesting from wastewater lagoons and was evaluated for this project. Experiments were conducted with laboratory-scale and pilot scale cross flow systems. Filtration membranes constructed of polyester and nylon with pore sizes of 1- micron and 5-micron were used at various engineering operating conditions to determine the optimal conditions for the system.

Results demonstrated that cross flow filtration was a suitable option for the algal vi harvesting without adding additional chemicals that may interfere with the production of biodiesel. The polyester membrane collected a larger mass of algae compared with the nylon membrane, and a small pore size of 1-micron retained more algae compared with the 5-micron pore size.

Cross flow filtration was demonstrated to be an effective method for harvesting algae from the Logan Lagoon wastewater, with a cost of approximately $2 million dollars. Although biodiesel fuel was not generated from the harvest algae, the predicted price of the algal biodiesel per gallon ranged from $7.17 to $7.18 in the first year.

Dissemination of Results:
Cross Flow Filtration for Mixed-Culture Algae Harvesting for Municipal Wastewater Lagoons. 2012. Digital Commons@USU, All Graduate Theses and Dissertations. 1162. Misheka Wilson. Biological Engineering Department, Utah State University

Algae retained by membrane for materials tested

Membrane Material	Pressure (PSI)	Algae Retained (%)
1-Micron Nylon	5.35	67
5-Micron Polyester	9.00	47
5-Micron Nylon	6.00	54

Additional projects presented at national professional meetings based on research in 2012 for the HERC Themes of recycling and air quality. Sponsorship of student attendance (travel expenses) were paid for by HERC.

1. Biodiesel from mixed culture algae via a wet extraction procedure for lipids. 2012. National Conference of the Institute of Biological Engineering. Indianapolis, ID. March 1-3. Ashik Sathish and Dr. Ronald C. Sims
2. Acetone, butanol, and ethanol production from wastewater algae. 2012. National Conference of the Institute of Biological Engineering. Indianapolis, ID. March 1-3. Joshua Ellis (PhD), Neal Hengge (BS), Ronald C. Sims, Charles D. Miller, and Jon Takemoto