Huntsman Environmental Research Center

BIENNIAL REPORT 2010-2011

PROJECTS AND PRODUCTS

Summary. During the years 2010-2011, HERC themes included biodegradation, recycling, and air quality. HERC projects included a summary presentation to Senator Robert Bennett about biodegradation in municipal wastewater at the Logan City Wastewater Treatment Lagoons. HERC collaborated with Logan City, with City and Utah Water Research Laboratory support, to test processes to upgrade the facility for nutrient removal, including a project with the College of Science to statistically analyze the spatial distribution of microalgae that remove nutrients that can cause algae blooms in lakes and drinking water reservoirs. The Huntsman On-Site Wastewater Treatment Training and Demonstration Site was utilized for several workshops and also for educating USU students in the Civil and Environmental Engineering Department.

2010

Project: Utah Wastewater Reclamation and Energy Production System

HERC Theme: Biodegradation, Air Quality, Recycling

Collaborators: Logan Environmental Department, USU Energy Dynamics Laboratory, Utah Water Research Laboratory, WesTech, Inc.

Students Supported: Nhean Chea (BS), Ashton Young (MS), Logan Christenson (MS), Reece Thompson (MS), Erick Griffiths (MS)

Results/Products/Outcomes:

Objectives

1. Use algae for phosphorus removal from water to achieve regulatory levels.
2. Make biofuels (biodiesel and natural gas) from algae
3. Evaluate Cutler Reservoir for reduction in phosphorus entering the reservoir

Simultaneous Biodiesel and Natural Gas Production

35 tons of algae per day (10,500 tons/yr)

Biodiesel = fuel for 140 trucks/year

Energy = power for 300 homes/year

Dr. Ron Sims explains the plan for accomplishing wastewater treatment and generating value products through utilizing wastewater as a resource for microbial biodegradation and transformations for recycling nutrients and improving air quality.

Dissemination of Results:
Presentation to Utah Senator Robert Bennett on August 25, 2009 that was used for discussions with the Logan City Water Board, Logan City Municipal Council, and the State of Utah Water Quality Board in 2010.

Project: Statistical Analysis of Wastewater Remediation

HERC Theme: Recycling, Air Quality, biodegradation

Collaborators: Math & Statistics Department at USU, Logan City Environmental Department, Utah Water Research Laboratory

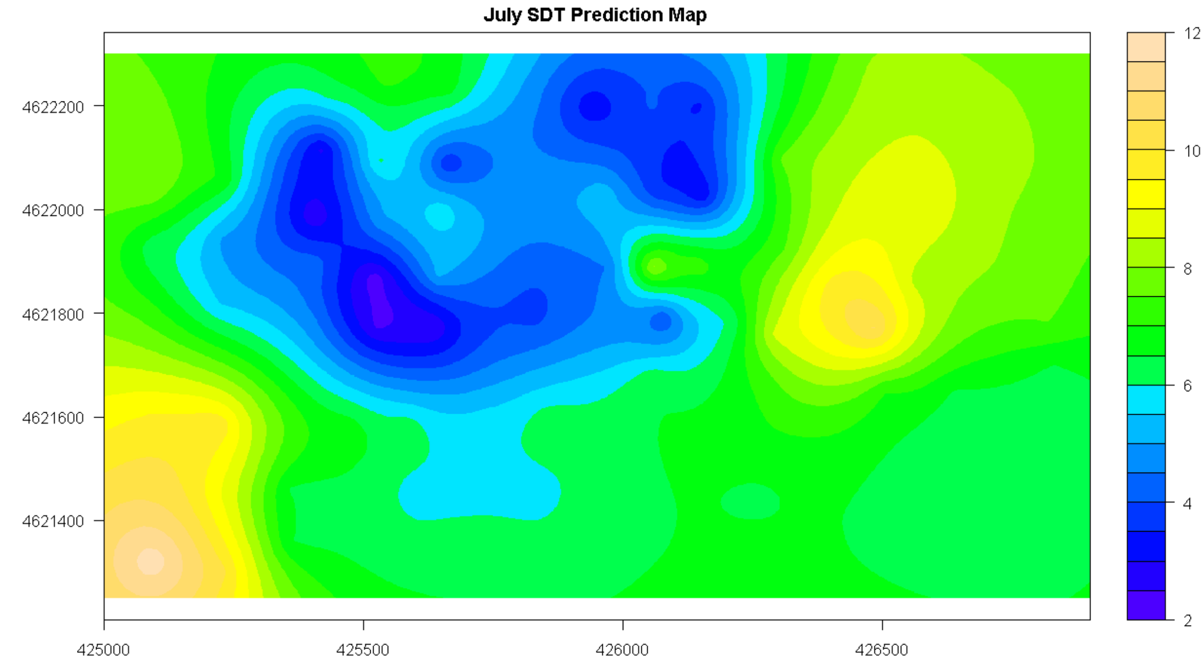
Students Supported: Jay D. Jones (MS), Austin Jensen (BS), Logan Christenson (MS)

Results/Products/Outcomes: The work reported here concerns the construction and analysis of experiments to spatially characterize concentrations of algae that take up carbon dioxide and phosphorus, and recycle phosphorus, and also provide a source of oxygen to improve biodegradation. The experiments described herein demonstrate that, by encouraging algal growth in the ponds, phosphorous may be removed from the system and effective methods for growing and harvesting algae are proposed. Because a manually sampled survey of the ponds is expensive and requires a great deal of resources, an alternative approach using aerial image data of the ponds was used to predict the manually sampled data of algae concentrations. Predicting algal concentrations using image data would mitigate the cost required of determining a location to harvest.

Two statistical prediction methods were used and compared including: (1) linear models, and (2) random forests. The methods were compared on the basis of the amount of variability in the data they are able to explain. Random forests outperform linear models in predictive ability when using only the image data for prediction. The results of this project provide a proof of concept that phosphorus can be removed from the Logan City lagoons by algae that can be grown and harvested efficiently. The methods of data collection were two-fold: (1) aerial data through the use of unmanned aerial vehicles (UAVs), and (2) physical sampling of the water at the surface of the lagoons. The least cost method is to employ UAV, however the effectiveness of predicting algae concentrations needed to be verified against physical sampling and chemical analysis of water samples.

The primary software used in the analysis of the data collected from these experiments is Statistical Analysis Software (SAS Statistical Institute 2003), while some graphics and summary statistics were produced using R statistical package (R Core Development Team 2009).

Results showed that the UAV method is effectiveness and less costly, and also more rapid, than the method of physical sampling followed by chemical analysis of the water samples.



Predicted values of algae concentration, where blue and purple areas denote areas of higher algae concentration. These values correlated with measured values of algae concentrations.

Dissemination of Results:

1. Statistical Analysis of Wastewater Remediation and Bio-fuels Production of Algae. 2010. Jay D. Jones. M.S. Thesis. Utah State University (Statistics Department) Major Advisor: Dr. Richard Cutler.

2. Predicting Algal Concentrations using Aerial Imaging and Statistical Analysis. 2010. Institute of Biological Engineering Conference, Cambridge, MA, March 4-6. Jay D. Jones, Austin Jensen, Logan Christenson, Richard Cutler.

Project: City of Logan Environmental Department Municipal Waste Management

HERC Theme: Biodegradation, Recycling, Air Quality

Collaborators: Carollo Engineering, State of Utah Department of Environmental Quality, Water Environment Association of Utah, Utah Water Research Laboratory

Students Supported: Erick Griffiths (MS), Shantanu Wahal (PhD), Dan Dye (PhD), Jay D. Jones (MS), Dan Nelson (MS), Andrew Elder (MS)

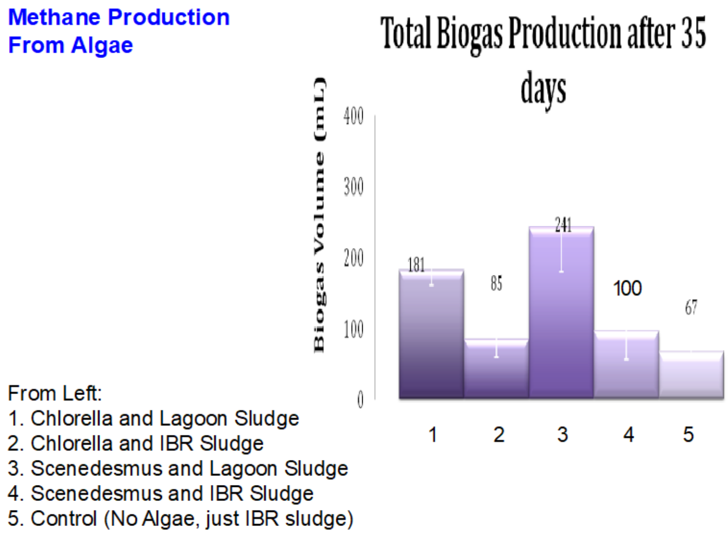
Results/Products/Outcomes: Biodegradation of wastewater cultivated algae showed significant increase in bioenergy production when algae, cultivated on wastewater, was added to the microbes under anaerobic conditions (no oxygen present).

Biomethane (Natural Gas) Production from Algae in Digester Bioreactor

A biodegradation reactor (Anaerobic Digester) (Volume 1,000 gallons) was provided by the Logan City Environmental Department in support of this project for testing the production of bioenergy in the form of methane from algae cultivated on municipal wastewater.

Results presented in the figure below show that when algae (Chlorella or Scenedesmus) was added to a reactor in the present of microbes in an environment with no oxygen present, there is a statistically significant increase in bioenergy (methane) production measured as volume of biogas, compared to a reactor where no algae were added (test reactor number 5). The highest production of bioenergy from the wastewater was achieved when the alga Scenedesmus was added to Logan Lagoon Sludge, which was sediment from the bottom of the lagoons that were already acclimated to the algae that grew at the top of the lagoons and then settled to the bottom by gravity.

This project demonstrated the potential to treat wastewater through anaerobic biodegradation and also produce a value product (methane), which also accomplishes recycling of nutrients within the reactor that prevents discharge of nutrients to the environment that causes algae blooms in receiving lakes and reservoirs.



IBR = Induced Blanket Reactor = Anaerobic Digestion Reactor
Lagoon Sludge = sediment from the bottom of the Logan City wastewater treatment lagoons

Dissemination of Results:
City of Logan Municipal Waste Management. 2010. Institute of Biological Engineering Conference, Cambridge, MA. March 4-6. Ronald Sims, Issa Hamud (Logan City Environmental Director), John Ellsworth, Kirsten Sims (MS), Brett Bossevian (MS)

2011

Project: Algae Treatment of Wastewater with Biofuels as By-Product

HERC Theme: Biodegradation, Conservation of Trees, Air Quality (GHG Reduction)

Collaborators: Logan City Environmental Department, Utah Department of Environmental Quality, Algae Biomass Organization (ABO), Utah Water Research Laboratory

Students Supported: Logan Christenson (MS), Ashton Young (MS)

Results/Products/Outcomes: A model algae biofilm system with cotton rope wound around light weight plastic barrels was designed, built, and tested in the Logan City Wastewater Lagoon (460 acres) for treatment of municipal wastewater. The treatment was designed to remove nutrients, specifically nitrogen and phosphorus that cause algal blooms in Cutler Reservoir, and degrade biodegradable organic chemicals in the water through microbial biodegradation. During the day (sunlight) algal growth removes nutrients and during the night (no sunlight) the microbes treat the organic chemicals through biodegradation. Growth of algae removes carbon dioxide from the atmosphere, thus reducing the greenhouse gas (GHG), thereby improving air quality. The algae, when harvested, can be used to make value bioproducts that are derived from trees, and therefore can contribute to the conservation of trees in support of HERC themes.

The floating Rotating Algae Biofilm Reactor (RABR) implemented on the Logan City Wastewater Treatment Lagoons. The cotton rope absorbs water containing nutrients and in the presence of sunlight acts like a soil to support the growth of algae.

Another bioreactor was designed (shown below) as a “retrofit” for lagoons that are no longer meeting requirements for nutrient removal was wastewater. The Rotating Algae Biofilm Reactor (RABR) can be added to a wastewater treatment lagoon before the wastewater is discharged to the environment.

The Rotating Algae Biofilm Reactor (RABR) is used to treatment wastewater immediately before discharge to the receiving stream. The RABR shown above is 6 feet in diameter and 5 feet wide, and rotates at 1 revolution per minute through the wastewater.

Dissemination of Results:

Algal Biofilm Production and Harvesting System for Wastewater Treatment with Biofuels By-Product. 2011. Presentation at the Institute of Biological Engineering Conference, Atlanta, GA, March 3-5. Logan Christensen, Ashton Young, Ronald C. Sims, and Issa Hamud

Project: Treatment of Wastewater Phosphorus Using Biomass Production

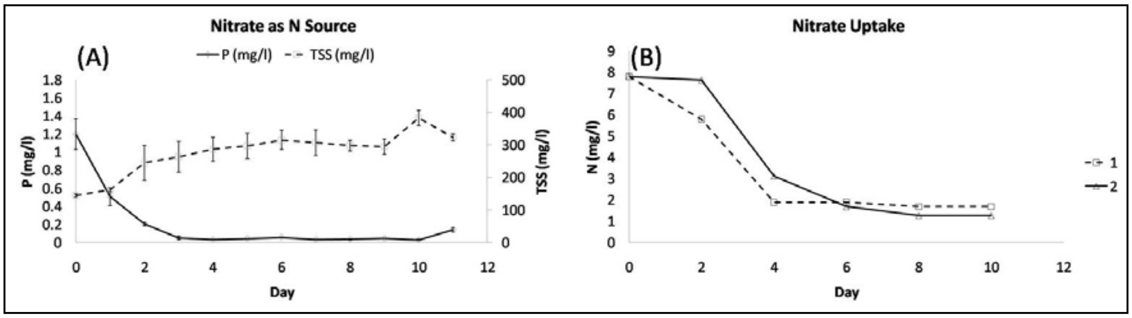
HERC Theme: Biodegradation, Air Quality, Recycling

Collaborators: Logan City Environmental Department, Utah Water Research Laboratory, Carollo Engineering, WesTech Engineering

Students Supported: Erick Griffiths (MS), Reese Thompson(MS), Daniel Dye (PhD)

Results/Products/Outcomes: The Logan City Environmental Department operates a facility that consists of 460 acres of lagoons (~ 5'deep) for biological wastewater treatment through biodegradation that meets targets for primary and secondary treatments including solids, biological oxygen demand, and pathogen removal. Significant natural algal growth occurs in these lagoons, which improves biodegradation through oxygenation whereby photosynthesis adds oxygen to the water and aids aerobic bacteria in the biodegradation of organic chemicals in the wastewater. Phosphorus, however, is non-volatile and stays in the water and likely cycles in and out of algal cells as they grow and die in the lagoons. In the near future, regulatory limits on phosphorus released from the Logan wastewater treatment facility are likely to become significantly lower to counter potential downstream algal blooms, that is, eutrophication. One way to potentially lower phosphorus levels in the wastewater effluent is through uptake into biomass in the form of algae that grow naturally in the Logan Wastewater Lagoons as well as in other Lagoons throughout the state of Utah. This project evaluated the ability of algae to uptake phosphorus in the Logan City Wastewater Treatment Lagoons, which is a critical problem and goal for the Logan City Environmental Department and for the state of Utah Department of Environmental Quality.

Logan City Wastewater Treatment Lagoons System for biodegradation of organic chemicals and cultivation of algae to add oxygen to the wastewater and to uptake nutrients from the water into biomass. Flow = 14 million gallons per day. Population served approximately 100,000.



A) P uptake with algae growth and nitrate uptake (B) over time in outdoor pilot raceway with nitrate as N source. 1 and 2 are replicates

Results show that phosphorus can be removed to less than 0.5 mg/L by uptake into algae biomass that grows naturally within the lagoon system. The algae that grow also uptake carbon dioxide that improves air quality by removing the greenhouse gas (GHG) from the atmosphere.

Dissemination of Results:

Algae Production, Harvesting, and Reaction for Biofuels in a 460-acre Lagoon System. 2011 Institute of Biological Engineering Conference, Atlanta, GA. March 3-5. Ronald Sims, Issah Hamud, Reese Thompson, Erick Griffiths, Daniel Dye (Utah State University)

Project: Role of Daphnia in Wastewater Treatment of Phosphorus

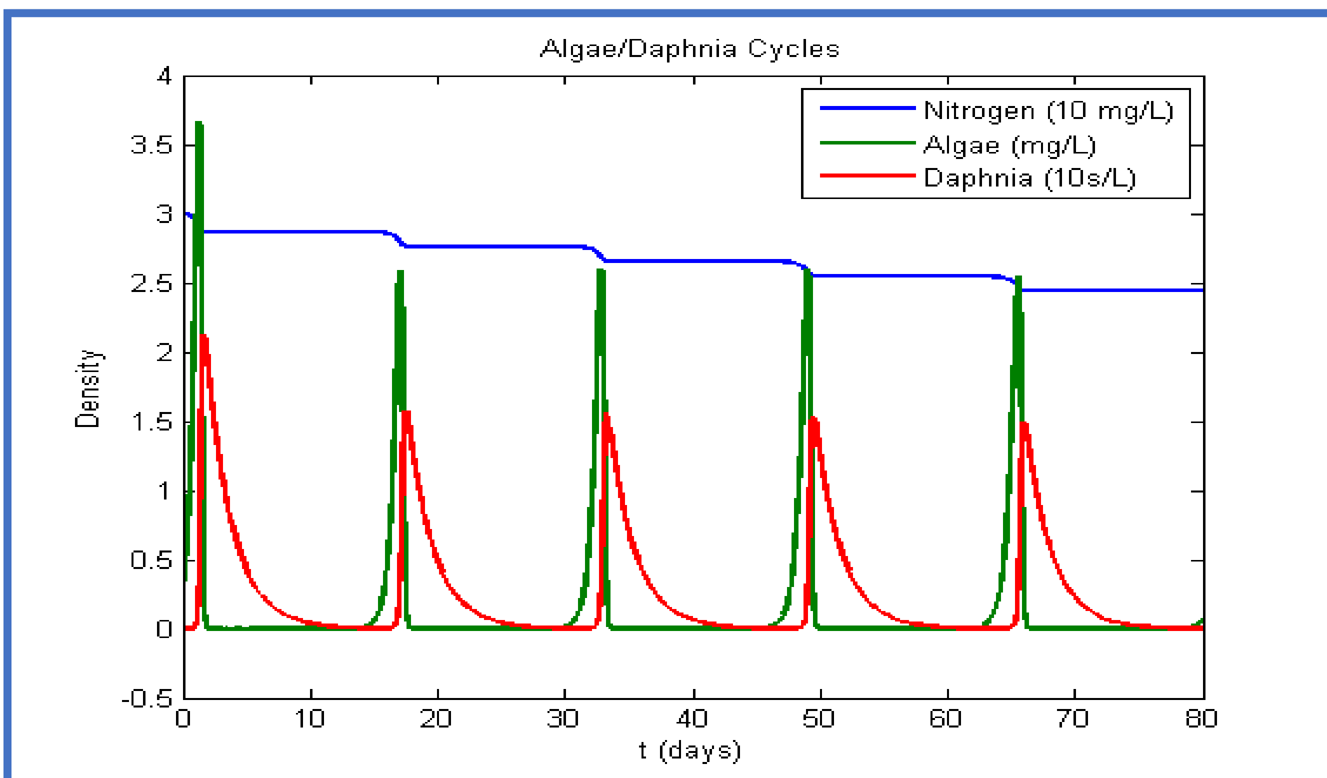
HERC Theme: Biodegradation, Recycling

Collaborators: Water Environment Association of Utah, Institute of Biological Engineering, Carollo Engineering, Utah Water Research Laboratory

Students Sponsored: Nhean Chea (BS), Kalie McCulloch (BS), Ashton Young (MS)

Results/Products/Outcomes: *Daphnia* (water fleas) consume algae in the Logan Lagoons, resulting in the release of phosphorus back into the wastewater, which leads to algal blooms (eutrophication) in Cutler reservoir. In order to remedy this environmental issue, a better understanding of the *Daphnia*-algae system is required. Our goal is to model the predatory relationship between *Daphnia* and algae in the Logan lagoons that can be applicable to other lagoon systems in Utah.

Our model correlates well with observations made throughout the summer months, with *Daphnia* population blooms occurring bimonthly. Optimum algae harvesting time for summer conditions can also be deduced from this model. By harvesting the algae before *Daphnia* population bloom ignites, phosphorus release and *Daphnia* population will be minimized.



Simulation of algae-*Daphnia* cycle. Daphnia feed on the algae and then both populations decline until another cycle is initiated.

Dissemination of Results:
Daphnia Impact on Logan Wastewater Lagoons. 2011. Presentation at the Institute of Biological Engineering Conference. Atlanta, GA. March 3-5. Nhean Chea, Kalie McCulloch, Ashton Young, and James Powel.