Environment and Natural Resources Trust Fund

M.L. 2020 Approved Work Plan

General Information

ID Number: 2020-062

Staff Lead: Michael Varien

Date this document submitted to LCCMR: August 13, 2021

Project Title: Technology For Energy-Generating Onsite Industrial Wastewater Treatment

Project Budget: $450,000

Project Manager Information

Name: Paige Novak

Organization: U of MN - College of Science and Engineering

Office Telephone: (612) 626-9846

Email: novak010@umn.edu

Web Address: https://cse.umn.edu/

Project Reporting

Date Work Plan Approved by LCCMR: August 13, 2021

Reporting Schedule: April 1 / October 1 of each year.

Project Completion: June 30, 2024

Final Report Due Date: August 14, 2024

Legal Information

Legal Citation: M.L. 2021, First Special Session, Chp. 6, Art. 5, Sec. 2, Subd. 04b

Appropriation Language: $450,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to improve water quality and generate cost savings by developing off the shelf technology that treats industrial wastewater on-site and turns pollutants into hydrogen and methane for energy. This appropriation is subject to Minnesota Statutes, section 116P.10.

Appropriation End Date: June 30, 2024

Narrative

Project Summary: We will advance an "off the shelf" technology to treat industrial wastewater onsite, turning pollutants into energy and treated water. This will lead to water quality benefits and cost savings.

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

In Minnesota the food- and beverage-processing industry, including dairies, malting plants, potato processing facilities, and breweries, is vibrant and provides economic opportunities in both urban and greater Minnesota communities. These industries are water intensive and many do not treat their wastewater onsite. Instead, they discharge their untreated wastewater, typically 20-100 times "stronger" or more concentrated than municipal wastewater, to a centralized municipal treatment plant. As a result:

- The industry is required to pay fees to the municipality to discharge the water to the municipal treatment plant, and
- The municipality has to expend energy to treat the (much stronger, more challenging, and potentially disruptive) industrial wastewater.

Our goal is to expand previous LCCMR-funded research to enable widespread onsite industrial wastewater treatment that turns pollutants into hydrogen and methane fuels and provides benefits to municipalities in the form of more predictable and easier wastewater treatment and lowered treatment costs. This work complements current federally-funded research to better leverage LCCMR dollars.

What is your proposed solution to the problem or opportunity discussed above? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and Milestones.

A previous successful LCCMR project formed the basis for this research, resulting in the development of first-generation technology that we have since improved upon. This new technology

- Is designed to be installed onsite at food- and beverage-processing facilities,
- Consists of two reactors, one to turn pollutants into hydrogen and a second to clean the water further and turn remaining pollutants into methane,
- Treats the wastewater using bacteria that are encased (or encapsulated) in non-toxic gel-like beads,
- Easily retains the beads within the reactor and protects the bacteria within the beads,
- Turns pollutants in the wastewater into hydrogen and methane by allowing the encapsulated bacteria to "eat" the pollutants in the wastewater much as we eat food, "exhaling" hydrogen and methane. The hydrogen and methane are used directly onsite as fuels for energy generation.

In addition, this new technology improves upon other treatment options by being very compact, creating energy from pollutants in the waste, and requiring much less energy to operate when compared to competing technologies.

After onsite treatment of this concentrated industrial wastewater, the treated wastewater is discharged to the municipal wastewater treatment plant. Because the industrial waste is pre-treated, it should be easier and cheaper to manage.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

Although we have demonstrated successful laboratory-scale operation of the technology with real wastewater, in its current form it is not easily scaled up and each new application requires customization and time-consuming testing. This limits its use. The proposed research would advance this technology by developing and verifying a predictive model that enables accurate a priori scale-up of the system by identifying the ideal bacteria concentration in the beads, bead size, retention time, and other operational parameters. This model will be verified experimentally. This model will be used to complement federally-funded concurrent research on additional experimental aspects of the technology.

Project Location

What is the best scale for describing where your work will take place?

Statewide

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

During the Project and In the Future

Activities and Milestones

Activity 1: Develop a mathematical model that describes the performance of the 2-reactor system incorporating encapsulated bacteria to be used for prediction

Activity Budget: $158,741

Activity Description:
A mathematical model will be developed that can accurately describe bacterial metabolism (i.e., biodegradation of industrial wastewater constituents), growth, escape, and product inhibition. This primarily mechanistic model will be based on a classic diffusion-reaction model; this is in contrast to our existing model which relies heavily on empirical parameters. The model will be built in Matlab or Python and will be verified experimentally (below, Activity 2). Sensitivity analyses will be performed.

Activity Milestones:

Description	Completion Date
Develop the mathematical framework of the model.	February 28, 2023
Verify the model using experimental data.	May 31, 2024
Translate model findings to ideal scenarios for treatment of a variety of wastewaters	June 30, 2024

Activity 2: Pre-pilot scale testing and model verification of the wastewater treatment system

Activity Budget: $213,259

Activity Description:
Perform pre-pilot laboratory experiments with several real wastewaters (brewery, candy, potato chip) to determine parameters for the model and verify the model predictions with additional experiments. For this activity, 100-mL to 1-L and larger flow-through reactors will be established with encapsulated biomass. The biomass leakage will be determined by monitoring the protein that leaves the reactor over time in reactors supplied with no food source. The biomass growth rate will be determined by harvesting encapsulated biomass and measuring the increase in bacteria with time. The inhibition will be determined by performing experiments with known quantities of inhibitory products present and observing the impact on biomass activity. These values will be incorporated into the model.

Model accuracy will be determined through experiments supplied with a variety of wastewaters and run under a variety of conditions (reactor volume, residence time, wastewater strength, bead size, initial biomass density, gas extraction rate).

Activity Milestones:

Description	Completion Date
Experimental determination of parameters for incorporation into model	April 30, 2023
Test model accuracy via additional experiments with multiple wastewater types	May 31, 2024

Activity 3: Other activity

Activity Budget: $78,000

Activity Description:
Because the project was in limbo for about 2 years we submitted a proposal on similar work to that initially proposed to the LCCMR to the US Department of Energy. We have recently been awarded that grant. This means that the federal funding can be leveraged for greater overall benefit and that the LCCMR project scope needed to change slightly to be

complementary rather than overlapping. This decreased the LCCMR requested budget by $78,000 and narrowed the scope. This is reflected in Activity 3, which identifies the funds that are not anticipated to be needed for the newly refined and narrowed LCCMR project.

Activity Milestones:

Description	Completion Date
Funds not anticipated to be used based on the newly received complementary federal grant.	June 30, 2024

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
William Arnold	University of Minnesota College of Science and Engineering	Dr. Arnold is a co-investigator on the project. He is an expert in chemical fate, transport, and water treatment. For the past 10 years he has been a pioneer in the development and modeling of polymer films for chemical containment. We have worked together on similar projects.	Yes
Natasha Wright	University of Minnesota College of Science and Engineering	Dr. Wright is a co-investigator on the project. She focuses on the design, modeling, and system optimization of decentralized water treatment systems, with a specialty in membrane-based separation processes. Over the last 6 years, she has piloted combined energy generation / water treatment systems in the United States, India, and Gaza.	Yes

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.
The target audience for results from this research will be environmental engineers and scientists in academia, professionals in the area of wastewater treatment, city managers and other local government officials, industry and trade organization personnel (for example, the Minnesota Craft Brewers Guild), the Minnesota Pollution Control Agency, Minnesota Department of Employment and Economic Development (DEED) and Metropolitan Council Environmental Services (MCES). Results will be disseminated through scholarly publications in peer-reviewed journals such as Environmental Science and Technology and Environmental Science: Water Research and Technology. Results from the research project will also be presented at regional conferences such as the Conference on the Environment and seminars and roundtables hosted by project partners (DEED and MCES).

The Minnesota Environment and Natural Resources Trust Fund (ENRTF) will be acknowledged through use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications per the ENRTF Acknowledgement Guidelines.

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this be funded?
We have recently been awarded federal funding that complements the proposed research and can therefore be leveraged for greater benefit. The project was tested at a small pilot-scale at the Fulton Brewery and the research and development needs are clearly identified. Our federal grant will facilitate complementary scale-up and experimental efforts, providing additional improvements that can be captured by the predictive mathematical models created in this research. MCES and state-wide trade organizations will be used to disseminate the work and ready the technology for wide deployment.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Methods to Protect Beneficial Bacteria from Contaminants to Preserve Water Quality	M.L. 2014, Chp. 226, Sec. 2, Subd. 03b	$279,000

Evaluation of Wastewater Nitrogen and Estrogen Treatment Options	M.L. 2014, Chp. 226, Sec. 2, Subd. 03d	$500,000
Wastewater Nitrogen Removal Technology to Protect Water Quality	M.L. 2017, Chp. 96, Sec. 2, Subd. 04b	$450,000
Improving Nitrogen Removal in Greater Minnesota Wastewater Treatment Ponds	M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04e	$325,000
Degrading Chlorinated Industrial Contaminants with Bacteria	M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04s	$150,000

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Novak, PI		Overall project supervision, experimental set up and operation, data interpretation.			27%	0.12		$40,170
Arnold, Co-PI		Provide guidance on the model construction and the experimental validation of the model.			27%	0.12		$40,211
Wright, Co-PI		Provide guidance on the model construction, verification, and sensitivity analysis.			27%	0.12		$27,159
Postdoctoral Researcher		Will focus on the experiments for model parameterization and verification.			20%	2		$132,372
Graduate Research Assistant		Will focus on the development of the model and its verification. Will perform sensitivity analysis.			43%	1		$104,468
							Sub Total	**$344,380**
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
	Tools and Supplies	Laboratory supplies, services, and analytical costs (includes, but is not limited to, chemicals for all analyses, supplies to maintain analytical equipment, supplies for reactor construction, pumps for lab-scale systems). A computer will be needed for the model development and testing. This computer will only be used for this project. These are all required and standard costs.	Supplies, pumps, are needed to construct and operate reactors in the lab. A computer is needed to develop and run the model. Additional supplies and chemicals are required to perform the experiments described, including analyses to determine treatment efficacy, analysis of the gases produced (quantity and chemical make-up) to determine how efficient the system is. A small amount of funds are included for maintenance of laboratory equipment.					$26,348
							Sub Total	**$26,348**

Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Mileage costs to go pick up wastewater from industries for use in experiments.	Travel to industrial sites is needed for wastewater collection.					$1,272
							Sub Total	**$1,272**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
		Funds not anticipated to be used based on the newly received complementary federal grant	Because the project was in limbo for about 2 years we submitted a proposal on similar work to that initially proposed to the LCCMR to the US Department of Energy. We have recently been awarded that grant. This means that the federal funding can be leveraged for greater overall benefit and that the LCCMR project scope needed to change slightly to be complementary rather than overlapping. This decreased the LCCMR requested budget by $78,000 and narrowed the scope. This is reflected in Activity 3, which identifies the funds					$78,000

			that are not anticipated to be needed for the newly refined and narrowed LCCMR project.					
							Sub Total	**$78,000**
							Grand Total	**$450,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	Because the project is overhead-free, overhead costs are provided in kind. The University of Minnesota overhead rate is 55% (equivalent to $186,530).	Laboratory space, electricity, and other overhead costs are provided in kind.	Pending	$186,530
			Non State Sub Total	**$186,530**
			Funds Total	**$186,530**

Attachments

Required Attachments

Visual Component

File: 00e0ad92-dd6.pdf

Alternate Text for Visual Component

The visual shows a picture of our current small pilot system set up at the Fulton Brewery and shows how the system can provide electricity for use at the industry site and discharges wastewater that has been pre-treated to a municipal wastewater treatment plant. The following benefits are shown: 1) Decreased costs for the municipality and industry, 2) Decreased energy use for the municipality for treatment, and 3) Resource Recovery. The following project outcomes are shown: Verified mathemati...

Optional Attachments

Support Letter or Other

Title	File
Background check form	fdb4635e-6f8.pdf

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

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Additional Acknowledgements and Conditions:

The following are acknowledgements and conditions beyond those already included in the above workplan:

Do you understand and acknowledge the ENRTF repayment requirements if the use of capital equipment changes?

N/A

Do you agree travel expenses must follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

Yes, I agree to the UMN Policy.

Does your project have potential for royalties, copyrights, patents, or sale of products and assets?

No

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

N/A

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

N/A

Does your project include original, hypothesis-driven research?

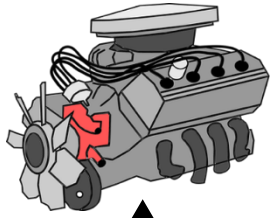
Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

Onsite wastewater treatment from food- and beverage-based industries will lead to clean water, energy production, and reduced costs.

START



electricity

END

Food- or beverage- processing industry

Hydrogen and methane gas to an engine

Untreated wastewater

Treatment technology

Treated water

Centralized municipal treatment plant

<u>Benefits</u>

- Decreased costs for the municipality and industry
- Decreased energy use for the municipality for treatment
- Resource Recovery

<u>Outcomes</u>

- Verified mathematical model to enable the predictable deployment of technology