Environment and Natural Resources Trust Fund

2022 Request for Proposal

General Information

Proposal ID: 2022-201

Proposal Title: Technology for Energy-Generating Onsite Industrial Wastewater Treatment

Project Manager Information

Name: Paige Novak

Organization: U of MN - College of Science and Engineering

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Project Basic Information

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.

Funds Requested: $352,000

Proposed Project Completion: June 30 2025

LCCMR Funding Category: Water Resources (B)

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

Narrative

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 (e.g., breweries vs. dairies) 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.

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: $144,228

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. The model will be based on a classic diffusion-reaction model, and modified. The model will be built in Matlab or in R 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
Incorporate experimentally determined parameters into the model and perform sensitivity analyses.	December 31 2023
Verify the model using experimental data.	May 31 2024

Activity 2: Pilot scale testing and design optimization of the wastewater treatment system

Activity Budget: $207,772

Activity Description:
Perform 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 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 additional experiments supplied with a variety of wastewaters and run under a variety of conditions (residence time, wastewater strength, bead size, initial biomass density).

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	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 modeling, design, 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

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 for the project 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

Project Manager and Organization Qualifications

Project Manager Name: Paige Novak

Job Title: Professor and Joseph T. and Rose S. Ling Chair of Environmental Engineering, Department of Civil, Environmental, and Geo- Engineering, University of Minnesota

Provide description of the project manager's qualifications to manage the proposed project.

B.S., Chemical Engineering, 1992, The University of Virginia, Charlottesville, VA.
M.S., Environmental Engineering, 1994, The University of Iowa, Iowa City, IA.
Ph.D., Environmental Engineering, 1997, The University of Iowa, Iowa City, IA.

Dr. Paige Novak will be responsible for overall project coordination. She has been studying the biological treatment of water and wastewater for over 20 years. Recent work has focused on the generation of energy from high-strength wastewater and the degradation of pollutants in wastewater to facilitate water reuse. She and Dr. William Arnold completed an LCCMR-funded project on the generation of energy from high-strength wastewater and obtained a patent on that work. They have also published several high-profile papers related to that work.

Organization: U of MN - College of Science and Engineering

Organization Description:
The University of Minnesota (UMN) is one of the largest, most comprehensive, and most prestigious public universities in the United States (http://www1.umn.edu/twincities/01_about.php). The College of Science and Engineering at the University of Minnesota is ranked among the top engineering and science academic programs in the country. The college includes 12 academic departments offering a wide range of degree programs at the baccalaureate, master's, and doctoral levels. Indeed, researchers within the College of Science and Engineering are on the leading edge of finding ways to solve some of the world's greatest problems by developing new forms of environment-friendly energy, designing new medical devices, improving digital and electronic technologies, and developing a strong national infrastructure. The College of Science and Engineering also offers students a rigorous, world-class education tailored to their interests and goals. The Department of Civil, Environmental, and Geo- Engineering (CEGE) at UMN is known for its pioneering work in analytical, computational, and experimental methods. We practice research excellence grounded in rigorous fundamentals for wide-ranging applications.

The PI has access to all of the facilities needed in CEGE to perform the described research.

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		$34,939
Arnold, Co-PI		Provide guidance on the model construction and the experimental validation of the model.			27%	0.12		$34,975
Wright, Co-PI		Provide guidance on the model construction, verification, and sensitivity analysis.			27%	0.12		$22,158
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		$103,841
							Sub Total	**$328,285**
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.					$22,443
							Sub Total	**$22,443**

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								
							Sub Total	**-**
							Grand Total	**$352,000**

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 $172,781).	Laboratory space, electricity, and other overhead costs are provided in kind.	Pending	$172,781
			Non State Sub Total	**$172,781**
			Funds Total	**$172,781**

Attachments

Required Attachments

Visual Component

File: 44404ff7-0c1.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: 1) New “off the sh...

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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?

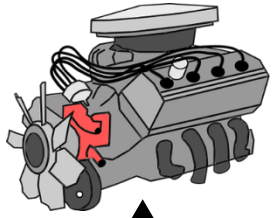
Yes

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