Environment and Natural Resources Trust Fund

M.L. 2022 Approved Work Plan

General Information

ID Number: 2022-087

Staff Lead: LCCMR General Universal Staff User

Date this document submitted to LCCMR: June 21, 2022

Project Title: High Temperature Anaerobic Digestion of Sewage Sludge

Project Budget: $208,000

Project Manager Information

Name: Timothy LaPara

Organization: U of MN - College of Science and Engineering

Office Telephone: (612) 624-6028

Email: lapar001@umn.edu

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

Project Reporting

Date Work Plan Approved by LCCMR: June 27, 2022

Reporting Schedule: March 1 / September 1 of each year.

Project Completion: June 30, 2025

Final Report Due Date: August 14, 2025

Legal Information

Legal Citation: M.L. 2022, Chp. 94, Art. , Sec. 2, Subd. 04b

Appropriation Language: $208,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to demonstrate that high temperature anaerobic digestion is effective at treating sewage sludge and preventing disease-causing microorganisms and antibiotic resistance genes from being released into the environment.

Appropriation End Date: June 30, 2025

Narrative

Project Summary: This research project will demonstrate that high temperature anaerobic digestion is highly effective at treating sewage sludge, particularly with respect to destroying disease-causing microorganisms and antibiotic resistance genes.

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

This proposed project will investigate that the use of high temperature anaerobic digestion as a better technology for treating the sewage sludge generated by Minnesota's municipal wastewater treatment facilities.

The State of Minnesota has more than 500 municipal wastewater treatment plants that generate more than 150,000 tons (300 million pounds) of sewage sludge each year. In Minnesota, only 1/3 of this sewage sludge is treated and beneficially re-used as a soil additive for agricultural purposes.

This proposed research project would directly compare the performance of high temperature anaerobic digestion (operated at temperatures of 120 to 140 degrees) versus conventional anaerobic digestion (operated at 95-98 degrees). Although high temperature anaerobic digestion is already in use within the State of Minnesota (for example, at the Western Lake Superior Sanitary District in Duluth), its use is uncommon because of a long-standing reputation for process instability. This proposed research will provide scientific evidence that this reputation for process instability is unfounded and that the performance of high temperature anaerobic digestion far exceeds other, more commonly used sewage sludge treatment technologies.

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

High temperature anaerobic digestion has had a poor reputation since the 1930s, when initial attempts at using the technology were unsuccessful; this poor reputation has largely stuck with this technology ever since, even though a similarly poor reputation associated with conventional anaerobic digestion has dissipated. This poor reputation is the primary cause for this technology being rarely used. The reality, however, is that because it operates at higher temperatures, high temperature anaerobic digestion should far exceed the performance of conventional anaerobic digestion (operated at human body temperature), particularly with respect to the inactivation of disease-causing organisms and antibiotic resistance genes. Simply put, the wide-spread application of high temperature anaerobic digestion for sewage sludge treatment would benefit both Minnesota's environment and the health of Minnesota's residents while costing approximately the same as conventional anaerobic digestion.

This proposed research will directly compare high temperature anaerobic digestion to conventional anaerobic digestion in laboratory-scale systems that simulate full-scale installations. We will directly compare rates of treatment (e.g., biogas production and solids destruction rates) and rates of pathogen inactivation (e.g., E. coli, SARS-CoV-2).

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?

On a regular basis (every 10-20 years), each of the 500+ wastewater treatment facilities in Minnesota is analyzed to ensure that ever-evolving regulations are satisfied and to upgrade facilities with newly developed technologies. This project should lead to more frequent use of high temperature anaerobic digestion at these facilities because it results in better sewage sludge treatment, greater use of treated sewage sludge for agricultural purposes, and improved public health. Remarkably, because the fuel for heating the digesters comes from biogas produced during treatment, high temperature anaerobic digestion can be installed at a similar cost as conventional anaerobic digestion.

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: Compare effectiveness of anaerobic digestion as a function of temperature

Activity Budget: $132,500

Activity Description:
This activity will involve the establishment of 6 bench-scale anaerobic digesters operated in parallel at different temperatures (ranging from 75 to 140 degrees). We will then measure and compare the performance of these digesters using conventional parameters like the destruction of total solids and volatile solids as well as the production of biogas (which includes both volume of biogas and the methane content of the biogas). In addition, we will explore novel performance parameters including the destruction of carbohydrates, proteins, ATP, RNA, and DNA. Bench-scale bioreactors will be fed untreated sewage sludge collected from a local wastewater treatment facility. This experimental design will be very novel as prior studies have not directly compared anaerobic digester performance as a function of temperature.

Activity Milestones:

Description	Approximate Completion Date
Initiate laboratory-scale anaerobic digesters	August 31, 2022
Acclimate anaerobic digesters and establish baseline performance standards	December 31, 2022
Determine performance characteristics as a function of temperature	August 31, 2023
Characterize microbial community composition as functions of temperature	March 31, 2024

Activity 2: Characterize the microbial community composition of the biomass from anaerobic digesters operated at different temperatures, especially the disease-causing organisms

Activity Budget: $75,500

Activity Description:
Because it is derived from human fecal material, one of the primary environmental problems posed by sewage sludge is that it contains substantial quantities of microorganisms that cause disease as well as antibiotic resistant bacteria. Conventional anaerobic digestion, however, is typically operated at approximately the temperature of the human body, which is not particularly effective at inactivating microorganisms that can grow inside a human body. In contrast, high temperature anaerobic digestion is operated at higher temperatures, which should make it superior to conventional anaerobic digestion with respect to inactivating microorganisms that cause disease in humans. This activity, therefore, will involve collecting biomass samples from bench-scale anaerobic digesters (see Activity 1) and then extracting and purifying DNA and RNA from these samples. Finally, quantitative polymerase chain reaction (qPCR) will be used to quantify pathogens and antibiotic resistance genes in these samples, allowing us to directly (and statistically) compare the effectiveness of high temperature anaerobic digestion versus conventional anaerobic digestion at inactivating pathogenic microorganisms and antibiotic resistance genes.

Activity Milestones:

Description	Approximate Completion Date
Simulate anaerobic digestion at different temperatures (same as Activity 1)	August 31, 2023
Extract and purify genetic material for analysis via PCR	December 31, 2023
Characterize the microbiome of anaerobic digesters operated at different temperatures	June 30, 2024
Quantify pathogens and antibiotic resistance genes in anaerobic digesters operated at different temperatures	December 31, 2024

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.
This project will primarily involve bench-scale research. I will help disseminate the research results by making presentations to the local wastewater treatment community and by publishing the results in the peer-reviewed literature. Research publications will be open access, which will help LCCMR staff (and other) promote this work. That is, I will retain the copyright of all published material, which will allow anyone to post the articles anywhere that they would like. I will also acknowledge the Environment and Natural Resources Trust Fund during all dissemination activities. I will use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications per the ENTRF Acknowledgment 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 work be funded?
This project should result in several high visibility research publications that will attract the attention of other scientists and engineers. This will, in turn, make receiving funding for additional research much easier from federal sources such as the National Science Foundation and the Department of Energy (the DOE has recently become interested in more energy-efficient infrastructure). This research should also lead to increased usage of this technology at full-scale municipal wastewater treatment facilities, which will create opportunities for research at full-scale installations.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Triclosan Impacts on Wastewater Treatment	M.L. 2014, Chp. 226, Sec. 2, Subd. 03c	$380,000
Wastewater Treatment Process Improvements	M.L. 2016, Chp. 186, Sec. 2, Subd. 04k	$398,000
Emerging Issues Account	M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 10	$439,000
Evaluate Emerging Pathogens in Lakes, Rivers, and Tap Water to Keep Drinking Water Safe	M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 04f	$325,000

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Timothy LaPara		Project Manager			26.7%	0.51		$116,022
Undergraduate Research Assistants		Perform experiments and analyze data			0%	1.2		$38,481
							Sub Total	**$154,503**
Contracts and Services								
University of Minnesota Genomics Center	Internal services or fees (uncommon)	UMGC provides at-cost access to state-of-the-art molecular/genetic equipment (e.g., next-gen DNA sequencing, droplet digital PCR), supplies, and technical expertise.				0		$15,000
							Sub Total	**$15,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Expendable reagents for quantitative polymerase chain reaction	These reagents are needed to characterize specific genes and organisms of importance to anaerobic digestion					$7,500
	Tools and Supplies	Miscellaneous chemicals, laboratory supplies (e.g., glassware)	Numerous chemical reagents will need to be purchased to collect samples, process these samples, analyze the samples, and preserve the samples.					$9,097
	Tools and Supplies	DNA and RNA extraction kits	Extract and purify DNA and RNA from anaerobic digester samples. DNA extraction kits are about $600 for 100 preps (i.e., $6 per sample) and RNA extraction kits are a similar price (i.e, $6 per sample). This will allow us to process 200 samples for DNA/RNA analysis.					$2,400

	Tools and Supplies	Shaker-Incubators	We will need at least 2 incubators ($3500 each) capable of shaking and controlling temperature to perform lab-scale anaerobic digester experiments					$7,000
							Sub Total	**$25,997**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	We will need to travel to a nearby wastewater treatment plant to collect untreated sewage sludge	Our research investigates the treatment of sewage sludge; we can only obtain this material from full scale treatment facilities					$3,000
	Conference Registration Miles/ Meals/ Lodging	I will identify a conference in Minnesota to attend to present our research results	Dissemination					$1,000
							Sub Total	**$4,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Printing	Poster printing	We will present our research results in poster format, which will require printing					$500
	Publication	Open access publication charges	We will publish our results in "open access" format so that LCCMR staff can better help us promote our research					$5,000

							Sub Total	**$5,500**
Other Expenses								
		Equipment repair	We will heavily use equipment that is already owned by the University of Minnesota; this money will be used to cover repair costs if this equipment breaks					$3,000
							Sub Total	**$3,000**
							Grand Total	**$208,000**

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	The University of Minnesota typically charges a 55% overhead rate for all research expenditures except for those on capital equipment and graduate student tuition. By law, the University of Minnesota does not charge this overhead on projects funded by the State of Minnesota.	Overhead.	Secured	$114,400
			Non State Sub Total	**$114,400**
			Funds Total	**$114,400**

Attachments

Required Attachments

Visual Component

File: 1d21f43a-58c.pdf

Alternate Text for Visual Component

The visual shows a photo of a full-scale anaerobic digester and a map of the State of Minnesota, with a star located over the City of Duluth, where a full-scale, high-temperature anaerobic digester is already in operation....

Optional Attachments

Support Letter or Other

Title	File
Research Addendum	950e83a8-c07.docx
Background Check Certification Form	ca29dda8-b25.pdf

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

Because of the reduced budget, I had to make numerous changes to this work plan. I delete Activity 3 from this work plan to reduce costs. I also changed the personnel substantially from involve me plus a graduate student to me plus undergraduate assistants. In doing this, I am hoping to take advantage of a year of sabbatical "leave" during the 2023-2024 academic year, which will allow me to focus on this project (i.e., I will not be teaching so I will be the technician doing most of the work -- the undergraduates will assist me). All of these changes are consistent with the Research Addendum that is currently under review.

I also substantially reduced the focus on antibiotic resistance genes (the primary focus of Activity 3). I will still analyze antibiotic resistance genes as part of Activity 2, but the extent of this work will be relatively minor.

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

High Temperature Anaerobic Digestion of Sewage Sludge

Anaerobic digestion is commonly used to treat sewage sludge, but high temperature anaerobic digestion is rare. An exception to this rarity can be found in Duluth (shown above), where high temperature anaerobic digestion has been successfully used for decades.