Environment and Natural Resources Trust Fund

M.L. 2024 Approved Work Plan

General Information

ID Number: 2024-161

Staff Lead: Lisa Bigaouette

Date this document submitted to LCCMR: June 5, 2024

Project Title: Novel Nutrient Recovery Process from Wastewater Treatment Plants

Project Budget: $486,000

Project Manager Information

Name: Bo Hu

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

Office Telephone: (612) 625-4215

Email: bhu@umn.edu

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

Project Reporting

Date Work Plan Approved by LCCMR: June 20, 2024

Reporting Schedule: June 1 / December 1 of each year.

Project Completion: June 30, 2027

Final Report Due Date: August 14, 2027

Legal Information

Legal Citation: M.L. 2024, Chp. 83, Sec. 2, Subd. 04g

Appropriation Language: $486,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to continue to develop an integrated process to promote nutrient removal and recovery and renewable energy production at rural municipal and industrial wastewater treatment plants. This appropriation is subject to Minnesota Statutes, section 116P.10.

Appropriation End Date: June 30, 2027

Narrative

Project Summary: This proposal requests renewed funding for a new integrated process with potential to promote nutrient removal/recovery and renewable energy production at rural municipal and industrial wastewater treatment plants (WWTP).

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

Many WWTPs typically have biological phosphorus (P) removal and anaerobic digestion (AD) to reduce sludge volume. These two processes affect each other, causing issues that impact performance and increase operating costs. The bio-P removal impacts AD by mineral precipitation and decreasing solids dewaterability. P mineral precipitation clogs piping and accumulates on mixers and in reactors, requiring costly maintenance. Dewatering performance can be reduced by 3 – 6% after bio-P is initiated, significantly increasing solids management costs. The cause of dewatering issues has been linked to the ratio of mono/divalent cations, ortho-P concentration and extracellular polymeric substances, however, the complete mechanism has not been defined. AD impacts bio-P removal by converting P bound in cell mass to a soluble form. The recycled P load may be greater than 50% of the total plant load, often requiring addition of expensive reduced organics such as methanol or metal salts to achieve the required treatment. Also, with existing processes, P recovery is more difficult by its mixture with a high concentration of biological solids. This requires use of expensive separation equipment such as fluidized bed reactors for P recovery, limiting its application only to a few large metro WWTPs; disproportionally affecting rural plants.

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.

Our study has identified a new treatment concept with great potential for cost effective P recovery, increased renewable energy production, and reduced current P related issues. The concept involves a short thermophilic first-stage acid AD, then solids are separated and P is recovered. Results from our current grant project demonstrate its potential value:

1. High P release/solubilization in 1st stage, 900-2000 compared to 100-300 mg/L P in conventional AD.
2. Treating waste activated sludge (WAS) separate from primary sludge (PS) minimizes reactor size and maximizes P release.
3. P can be recovered as Brushite or Struvite minerals, both valuable fertilizer components.
4. Addition of concentrated waste helps lower pH for achieving maximum P release. This will enable WWTP's significant capacity to treat food waste for renewable energy production.
5. Separated solids from 1st stage AD requires additional AD treatment along with the PS stream and existing reactors can be utilized for this step.

Continued research is needed to develop this concept:

1. Study addition of food wastes in acid AD.
2. Study options for solid/liquid separation.
3. Refine economics related to Brushite or Struvite as the recovered P mineral.
4. Integrate new concept to current WWTP operations

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?

We will develop an integrated process with following specific project outcomes:

- Effective P removal without metal salts, protecting rivers and lakes.
- Lower cost and higher capture for P recovery systems, increasing their use and generating a valuable P mineral.
- Reducing maintenance costs at WWTPs and allowing land application of biosolids in areas with P load limitations.
- Reducing N recycle from AD process, resulting in lower energy use, increased applicability of bio-P process, and

reduced chemical use.

- Potential increased renewable energy production from co-digestion of food waste and wastewater sludge.
- Potential application to WWTP with and without primary clarifiers.

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?

In the Future

Activities and Milestones

Activity 1: Lab-scale study to determine addition of food waste and ratios to activated sludge on nutrient release/recovery and bioenergy production

Activity Budget: $152,140

Activity Description:
The lab-scale system used in our current work will be modified to include co-digestion of wastewater sludge and food waste. Thickened waste activated sludge (TWAS) from a local WWTP will be mixed with different types of food waste at various ratios (e.g., wet weight ratios of 5-30:1), and then used as the feeding substrate for the first-stage thermophilic acid AD with a hydraulic retention time (HRT) of 2-5 days. The effects of food waste types and mixing ratios on the thermophilic acid AD performance, especially on the nutrient release (e.g., phosphorus release, volatile fatty acids (VFAs) production, and ammonia generation), will be documented under different operation conditions (e.g., HRT, pH, etc.). Subsequently, the effluent from the thermophilic digester will go through a solid-liquid separation step: the solid portion with undigested organics will be recombined with thickened primary sludge (TPS) for a conventional mesophilic AD treatment, whereas the liquid portion will go through the nutrient recovery process. Typically, AD at WWTP cannot handle higher food waste addition because it will deteriorate or acidify the reactor, causing a thorough process failure. It will be beneficial to our first-stage AD system since lower pH will release more P.

Activity Milestones:

Description	Approximate Completion Date
Establish a modified lab-scale system to co-digest mixed TWAS and food waste	September 30, 2024
Report biogas production and nutrient release from thermophilic acid-AD of mixed TWAS and food waste	November 30, 2024
Summarize phosphorus recovery with minimal chemical use and second-stage AD with highest biogas production	June 30, 2025

Activity 2: Lab-scale assays to select optimal solid-liquid separation without compromising conventional AD treatment

Activity Budget: $155,183

Activity Description:
After the first-stage thermophilic acid AD, a portion of the organics in the mixed TWAS and food waste will be degraded and the nutrients will be released into the liquid stream. However, due to the complexity of the sludge composition, the dewatering process may be difficult. Hence, different methods (e.g., centrifugation, belt filter press, ultra filter, etc.) will be tested to separate the discharged effluent. The volume ratios between the liquid and solid portion will be determined among different methods. Typically, a higher liquid volume means a better separation process: more dissolved phosphorus can be recovered and more VFAs can be converted to biogas for bioenergy production. Nonetheless, a more thorough separation process usually requires higher energy input and longer processing time. Besides, a more thickened sludge cake with a higher solid content might also increase the loading of the conventional AD reactor as stated in Activity 1. Therefore, the relationship between the solid-liquid separation and the subsequent P recovery, second-stage biogas generation, and conventional AD operation will be patterned, especially on the energy aspect. With this exploration, a suitable solid-liquid separation method will be selected, and the optimum separation conditions will be determined accordingly.

Activity Milestones:

Description	Approximate Completion Date
Test and compare different methods to separate solid and liquid from discharged thermophilic AD effluent	November 30, 2025
Select optimum solid-liquid separation method and determine most efficient operation conditions	February 28, 2026
Finalize the operation conditions of pilot-scale system treating TPS/TWAS and disseminate in technical journals	June 30, 2026

Activity 3: Pilot-scale process research and techno-economic assessment

Activity Budget: $178,677

Activity Description:

Activity 3 involves modification of current research pilot-scale system to include co-digestion of TWAS and food waste, solid-liquid separation, and phosphorus recovery. This pilot-scale system will be operated in our lab using TWAS and TPS samples from local WWTP with bio-P and AD processes (supporting letter attached), and the data obtained will confirm the lab-scale work in Activities 1 and 2 (i.e., thermophilic acid AD for nutrient release, solid-liquid separation, P recovery through chemical dosing, and high-rate AD for biogas production) with a much larger working volume of the feeding materials (i.e., mixed TWAS and food waste). A fine-tuning strategy considering the reactor size changes will be established to maintain the optimum operation performance of such a pilot-scale system. In addition, the full and continuous operation of this pilot-scale system will provide reasonable data for a techno-economic assessment. The expenses include equipment purchase and construction, chemical reagents, electricity usage, and labor in system installation and operation/maintenance; the monetized benefits include improved food waste disposal, phosphorus recovery for further utilization such as fertilizer, enhanced biogas production, and eased discharging of effluents with less nutrients. Finally, the economic feasibility of the system deployment in WWTPs will be addressed.

Activity Milestones:

Description	Approximate Completion Date
Establish a pilot-scale experimental system digesting mixed TWAS and food waste	September 30, 2026
Stabilize and monitor pilot-scale two-stage AD process and solid-liquid separation performance	February 28, 2027
Optimize the overall pilot-scale process and report the final overall process operation conditions	April 30, 2027
Conduct techno-economic analysis based on the pilot-scale process and report the process economic feasibility	June 30, 2027

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.
We will continue working with the Office of Technology Commercialization at University of Minnesota to follow their steps on the patent application. The proposed research can be used by design engineers soon after the work is completed for application at new or existing WWTPs. Our team will continue our communications with Metro Council and open to any enquires from other wastewater treatment plants about potential applications of this technology. We intend to present the results as they are compiled via LCCMR reporting, publishing in scientific and engineering journals and conference presentations. The Environment and Natural Resources Trust Fund will be acknowledged with all these dissemination efforts.

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?
The proposed research can be used by design engineers soon after the work is completed for application at new or existing WWTPs, especially those small ones at Greater Minnesota. Our team intends to present the results as they are compiled via LCCMR reporting, publishing in scientific and engineering journals and conference presentations. Our team will also present the process and research results to wastewater treatment system vendors/manufacturers. Potential vendors include Suez, Centrysis and Ovivo. If additional study is needed, funding may be pursued through the EPA Small Business Innovation Research program and USDA Rural Development program.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Novel Nutrient Recovery Process from Wastewater Treatment Plants	M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 04b	$200,000

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Researcher		scientific staff, working on experimental design and data collection			36.8%	2.25		$209,331
Professor		Principal Investigator, coordinate the research efforts, design experiments and write project reports			36.8%	0.3		$62,800
Researcher		scientific staff, working on experimental design and data collection			36.8%	2.25		$167,465
							Sub Total	**$439,596**
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
	Equipment	A pilot scale bioreactor for phosphorus removal will be built in the first year and operated at a local wastewater treatment in the second project year to scale up the lab developed process. The components of this pilot scale reactor includes carboy, pumps, air compressor, insulation, filter device etc	This pilot scale reactor will enable us to test our proposed process in the real wastewater treatment plant					$20,391
	Tools and Supplies	Chemicals, analysis kits, and personal protection supplies such as gloves, masks, etc.	materials for lab experiments					$24,483
							Sub Total	**$44,874**
Capital Expenditures								
							Sub Total	-
Acquisitions and Stewardship								
							Sub Total	-
Travel In Minnesota								

	Miles/ Meals/ Lodging	Within-state travel using university vehicles, gas, standard IRS mileage rate	Trips to go to site for collection of waste samples					$1,530
							Sub Total	**$1,530**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$486,000**

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				
In-Kind	Since this project does not charge any indirect cost, therefore University of Minnesota matches the in kind service F&A. The current indirect cost rate is 55% of the direct total project cost without capital equipment.	UM F&A	Secured	$256,085
			State Sub Total	**$256,085**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**$256,085**

Attachments

Required Attachments

Visual Component

File: ab7e855e-3ed.docx

Alternate Text for Visual Component

This visual shows the differences between the current process and what we propose to develop....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
Support letter from Metro Council Wastewater treatment plants	0d6453f3-521.pdf
SPA cover letter	437f35a4-662.pdf

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

We change the patent potential in the general information session. We modified each milestone based on the reviewer suggestions.

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, sale of products and assets, or revenue generation?

Yes

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

Yes

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

No

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?

No