Environment and Natural Resources Trust Fund

2024 Request for Proposal

General Information

Proposal ID: 2024-161

Proposal Title: Novel Nutrient Recovery Process from Wastewater Treatment Plants

Project Manager Information

Name: Bo Hu

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

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Project Basic Information

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).

Funds Requested: $486,000

Proposed Project Completion: June 30, 2027

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?

In the Future

Narrative

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.

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
Complete lab setup modification to study co-digestion of TWAS and food waste	September 30, 2024
Document biogas production and nutrient release from thermophilic acid-AD of mixed TWAS and food waste	November 30, 2024
Study 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, dynamic membrane, 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 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
Continuous operation and optimization of pilot-scale system treating TPS/TWAS.	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
Complete pilot-scale system setup	September 30, 2026
Stabilize and monitor two-stage AD process and solid-liquid separation	February 28, 2027
Optimize overall process	April 30, 2027
Techno-economic analysis	June 30, 2027

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

Project Manager and Organization Qualifications

Project Manager Name: Bo Hu

Job Title: Professor

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

Dr. Bo Hu is a Professor at Department of Bioproducts and Biosystems Engineering, University of Minnesota. With more than 20 years of active research experience specifically in biomass utilization, fermentative conversion, and waste management, he is leading projects to remove phosphorus from manure and from wastewater in the septic tank systems, projects to use plants to remove pollutants from soil and water, projects on synthetic ecology in lichen biofilm formation by co-culturing mixotrophic microalgae and filamentous fungi, and projects to upcycle low quality agricultural byproducts to nutritional animal feeds. Dr. Hu's team at UMN has set up several standard procedures such as 16s rDNA based microbial analysis by using high-throughout pyrosequencing methods to study the microbial species in the waste treatment processes, ITS sequences to identify fungal species. His team is also developing several conversion platforms, such as lichen biofilm co-cultivation of fungi and microalgae, pelletized fungal fermentation, and solid and hemi-SolidSF of filamentous fungi, to produce bioprducts and biofuel from agricultural waste and residue, and to remove nutrients and pollutant from contaminated water.

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

Organization Description:

In the College of Food, Agricultural and Natural Resources Sciences (CFANS) at the University of Minnesota, we look at the bigger picture. When we envision a better tomorrow, it includes disease-resistant crops, products that protect our health, lakes free from invasive species, and so much more. We use science to find answers to Minnesota and the world's grand challenges and solve tomorrow's problems. Almost 93 percent of students who earn CFANS undergraduate degrees find jobs in their career field or enter graduate school within six months of graduation.

The Department of Bioproducts and Biosystems Engineering, in CFANS, discovers and teaches solutions for the sustainable use of renewable resources and the enhancement of the environment. We discover innovative solutions to address challenges in the sustainable production and consumption of food, feed, fiber, materials, and chemicals by

integrating engineering, science, technology, and management into all degree programs.

We have a public impact through community engagement and extension efforts. We develop and deliver high quality, regionally and nationally-recognized research-based programs to meet current and emerging needs of industry and communities. We also have a long-standing tradition of close partnerships with alumni, industry professionals, organizations, government agencies, donors and community members.

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....

Optional Attachments

Support Letter, Photos, Media, Other

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

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

Does your project include the design, construction, or renovation of a building, trail, campground, or other capital asset costing $10,000 or more?

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?

No