



# Environment and Natural Resources Trust Fund

M.L. 2021 Approved Work Plan

## General Information

**ID Number:** 2021-115

**Staff Lead:** Corrie Layfield

**Date this document submitted to LCCMR:** July 21, 2021

**Project Title:** Novel Nutrient Recovery Process from Wastewater Treatment Plants

**Project Budget:** \$200,000

## Project Manager Information

**Name:** Bo Hu

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

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## Project Reporting

**Date Work Plan Approved by LCCMR:** July 20, 2021

**Reporting Schedule:** December 1 / June 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. 6, Sec. 2, Subd. 04b

**Appropriation Language:** \$200,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to conduct lab- and pilot-scale tests of a new process to promote nutrient removal and recovery at rural municipal and industrial wastewater treatment plants for water protection and renewable energy production.

**Appropriation End Date:** June 30, 2024

## Narrative

**Project Summary:** This proposal requests 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; disproportionately affecting rural plants.

**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.**

We are proposing a new integrated process, including thermophilic acid AD (TAAD) followed by dewatering, P recovery and high rate AD (HRAD) that address above issues (see attached process flow diagrams of conventional/new systems). The first step is the TAAD operated at 55°C for 2–4 days hydraulic retention time (HRT) in order to hydrolyze organics to volatile fatty acids (VFA), and P to soluble phosphate. The second step is dewatering and P recovery. TAAD effluent contains higher concentration phosphate than conventional AD, exceeding 500 mg-P/L. Dewatering of this effluent has been tested by Centrysis, documenting high cake solids concentrations and P recovery (up to 84%). Via lime/magnesium hydroxide dosing, valuable P minerals including brushite (CaHPO<sub>4</sub>) and struvite (MgNH<sub>4</sub>PO<sub>4</sub>) can be recovered from the liquid effluent. These P minerals can be used as P fertilizer, readily available for crop uptake. Finally, the effluent after P recovery contains high concentration of VFAs that can be recycled as a source of reduced organics for bio-P treatment, or sent to HRAD for conversion to renewable biogas energy. HRAD is able to operate at short HRTs of below 2 days as compared to over 20 days in conventional AD.

**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?**

This new, integrated process has potential to improve the efficiency and effectiveness and reduce the operation costs of bio-P and AD in rural WWTPs, thus promoting their use. Specific advantages include:

- Higher P recovery than current systems, better integrated at lower costs.
- Recovery of more valuable P minerals, increasing the application and protecting rivers and lakes.
- Reducing maintenance costs at WWTPs, improving dewaterability, allowing land application of biosolids in areas with P load limitations, and reducing transportation costs.
- More stable AD, less potential for foaming, significant reduction in time/tank volume and promoting AD as means of generating renewable bioenergy.

## 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: Set-up and test of lab-scale experimental system

**Activity Budget:** \$101,305

#### Activity Description:

A lab-scale experimental system will be set up to study this new process. Thickened primary sludge (TPS) and thickened waste activated sludge (TWAS) will be collected from local WWTPs as the test substrates. TPS and TWAS will be characterized and fed into the first-stage TAAD at 55°C and an HRT of 2-4 days. The P solubilization and VFA production in the effluent will be analyzed to evaluate the substrate hydrolysis and degradation in TAAD, and the fecal coliform destruction will also be monitored. Subsequently, solid-liquid separation will be applied to assess the dewaterability of the effluent after TAAD. The dewatered cake solids will be processed as biosolids for land application, whilst lime or magnesium hydroxide will be dosed into the liquid phase to capture and recover P in the form of brushite and struvite. The effects of varied reagent dosage on P recovery will be recorded. After P recovery, the liquid effluent rich in VFA will be fed into the third-stage HRAD for biogas generation. The correlation between the VFA loading and biogas production will be graphed. The optimum operation parameters of this three-stage system will be obtained finally.

#### Activity Milestones:

Description	Completion Date
Lab-scale three-stage experimental system set-up.	August 31, 2021
TPS/TWAS characterization and first-stage TAAD optimization.	November 30, 2021
Maximum P recovery with minimum reagent dosage in the second stage.	March 31, 2022
Interim report on the lab-scale system performance.	June 30, 2022
Correlation between VFA loading and biogas production in the third-stage HRAD.	June 30, 2022

### Activity 2: On-site demonstration of a pilot-scale system

**Activity Budget:** \$98,695

#### Activity Description:

With the establishment of lab-scale three-stage system and the optimization of operation parameters obtained in Activity 1, a pilot-scale system will be built and installed at or near a local WWTP. This pilot-scale three-stage system confirm the lab-scale experimental results (i.e., P solubilization and organic hydrolysis in TAAD, P recovery through lime/magnesium hydroxide dosage, and biogas production of VFA-rich liquid effluent in HRAD) with a much larger working volume of TPS/TWAS. The full and continuous operation of this pilot-scale system will provide a new insight of this novel integrated process on future actual deployment in WWTPs. After a successful demonstration, a techno-economic assessment of the proposed system will be conducted, thus addressing the economic feasibility of the implementation of this integrated three-stage system for improved bio-P recovery and biofuel production. The expenses resulting from the on-site pilot-scale demonstration will be used for the cost analysis, including equipment purchase and construction, reagents, electricity and fuel usage, and labors in the installation and operation/maintenance. The corresponding value increase due to biosolids sale, P recovery for further utilization, biogas production, and eased discharging of effluents with lower P and organics will be monetarized in the benefit analysis.

#### Activity Milestones:

Description	Completion Date
On-site pilot-scale system construction and installation.	September 30, 2022
Continuous operation and optimization of pilot-scale system treating TPS/TWAS.	March 31, 2023
Techno-economic assessment of this three-stage system including expenses and monetarized benefits.	June 30, 2023
Final report on both the lab-scale system and pilot-scale demonstration performances.	June 30, 2023



## 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 proposed research can be used by design engineers soon after the work is completed for application at new or existing WWTPs. 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. Environment and Natural Resources Trust Fund 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 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 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
Next Generation Large-Scale Septic Tank Systems	M.L. 2014, Chp. 226, Sec. 2, Subd. 08g	\$258,000
Extracting Deicing Salt from Roadside Soils with Plants	M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04i	\$360,000

## Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	\$ Amount
<b>Personnel</b>								
Researcher		scientific staff, working on experimental design and data collection			36.5%	2		\$144,089
Professor		Principal Investigator, coordinate the research efforts, design experiments and write project reports			36.5%	0.08		\$13,855
							<b>Sub Total</b>	<b>\$157,944</b>
<b>Contracts and Services</b>								
							<b>Sub Total</b>	-
<b>Equipment, Tools, and Supplies</b>								
	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					\$25,000
	Tools and Supplies	Chemicals, analysis kits, and personal protection supplies	materials for lab experiments					\$11,662
							<b>Sub Total</b>	<b>\$36,662</b>
<b>Capital Expenditures</b>								
							<b>Sub Total</b>	-
<b>Acquisitions and Stewardship</b>								
							<b>Sub Total</b>	-
<b>Travel In Minnesota</b>								

	Miles/ Meals/ Lodging	Within-state travel using university vehicles, standard rate applies	Trips to go to site for collection of waste samples					\$2,040
							<b>Sub Total</b>	<b>\$2,040</b>
<b>Travel Outside Minnesota</b>								
							<b>Sub Total</b>	-
<b>Printing and Publication</b>								
	Publication	Publication cost for two journal articles	To disseminate our research in scientific journals					\$3,354
							<b>Sub Total</b>	<b>\$3,354</b>
<b>Other Expenses</b>								
							<b>Sub Total</b>	-
							<b>Grand Total</b>	<b>\$200,000</b>



Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
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## Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
<b>State</b>				
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 54% of the direct total project cost without capital equipment.	UM F&A	Secured	\$95,112
			<b>State Sub Total</b>	<b>\$95,112</b>
<b>Non-State</b>				
			<b>Non State Sub Total</b>	-
			<b>Funds Total</b>	<b>\$95,112</b>

## Attachments

### Required Attachments

#### *Visual Component*

File: [4a7a9870-3f9.pdf](#)

#### *Alternate Text for Visual Component*

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

### Optional Attachments

#### *Support Letter or Other*

Title	File
SPA approval to submit	<a href="#">20db0704-3ad.pdf</a>
Approved research addendum	<a href="#">aafe232b-78b.docx</a>
Background check certification form	<a href="#">0cdcc562-a86.pdf</a>

## Difference between Proposal and Work Plan

### *Describe changes from Proposal to Work Plan Stage*

We added the dissemination plan for our research results and also the acknowledgement policy. We deleted the collaboration partner because Jim Postiglione no longer works at HR Green and will be hired as researcher to work on the project. So he is no longer identified as collaboration partner anymore. The other items are same as the proposal.

## 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

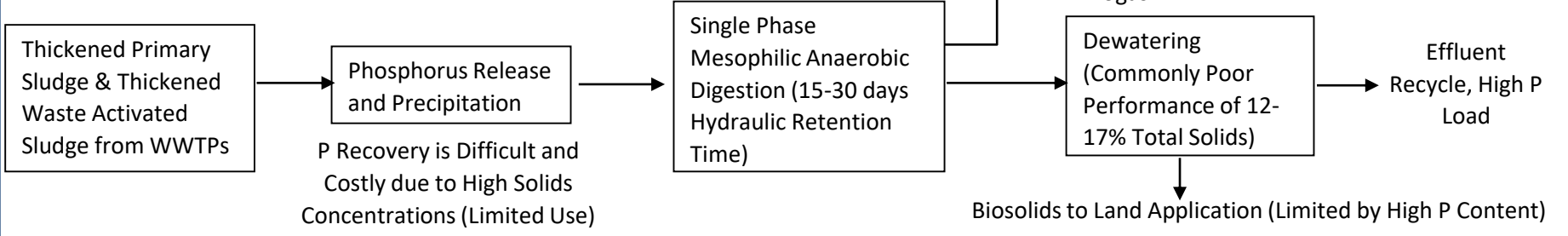
# Novel Nutrient Recovery Process from Wastewater Treatment Plants

Bo Hu, University of Minnesota, 612-625-4215, [bhu@umn.edu](mailto:bhu@umn.edu)

Environment and Natural Resources Trust Fund

Project Summary: This proposal requests 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).

## TYPICAL CURRENT PROCESS:



## EXISTING PROBLEMS:

Rural and smaller wastewater treatment plants typically have difficulties in recovering phosphorus, primarily because their anaerobic digestion and biological P removal steps are negatively affecting each other, causing costly maintenance, poor dewaterability, and additional equipment requirements

## BENEFITS FROM THE NEW PROCESS:

- Higher P recovery, better integration at lower costs.
- Recovery of more valuable P minerals, increasing the application and protecting rivers and lakes.
- Reducing maintenance costs at WWTPs, improving sludge dewaterability, allowing land application of biosolids in areas with P load limitations, and reducing transportation costs.
- More stable AD, less potential for foaming, significant reduction in time/tank volume, and promoting renewable bioenergy production by means of high-rate anaerobic digestion.

## EXPERIMENTAL PLAN:

- Lab scale experimental system
- On-site demonstration of a pilot-scale system

## NEW INTEGRATED PROCESS:

