Environment and Natural Resources Trust Fund

2022 Request for Proposal

General Information

Proposal ID: 2022-134

Proposal Title: Algal Granule Bioreactors for Nitrogen and Phosphorus Removal

Project Manager Information

Name: Satoshi Ishii

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

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Project Basic Information

Project Summary: This project will develop novel algae bioreactors to reduce nitrogen and phosphorus concentrations in agricultural runoff, thereby improving surface water quality.

Funds Requested: $200,000

Proposed Project Completion: June 30 2024

LCCMR Funding Category: Small Projects (H)

Secondary 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.

Contamination of surface waters with nitrogen (N) and phosphorus (P) can lead to eutrophication in rivers, lakes, and oceans, causing significant negative impacts on human and ecosystem health. Agricultural runoff is one of the main sources of these nutrients. Efforts have been made to reduce N and P runoff from agricultural fields, but it is still difficult to control N and P contaminations. Edge-of-the-field bioreactors such as woodchip bioreactors have been installed in Minnesota to remove these nutrients. However, one of the major challenges of the current bioreactor systems is the low microbial activities (and therefore low nutrient removal) due to low-temperature and high-nutrient runoff that occur in early spring. In this project, we propose to develop novel bioreactors to simultaneously reduce N and P from agricultural runoff in cold conditions, by using cold-adapted algae.

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.

The overall goal of this project is to improve water quality by reducing N and P concentrations in agricultural runoff. To achieve this goal, we will develop novel algae bioreactors. Algae grow fast in response to N and P in water and accumulate these nutrients in their biomass. Therefore, by harvesting algal biomass, we can reduce N and P concentrations in water. In the proposed algae bioreactor, microbial granular sludge technology will be used to facilitate the separation of algal biomass from water. Microbial granules are densely packed microbial structures, which have been used for wastewater treatment. In addition, algal granules have been found in natural environments. We previously identified the occurrence of microbial N removal processes in naturally occurring algal granules on the glacier ice. By creating similar N-removing algal granules in bioreactor conditions, we will be able to efficiently remove N and P from contaminated waters in low-temperature conditions.

In this project, we will first develop laboratory-scale algal granule bioreactors (Activity 1). We will optimize the reactor operation conditions to enhance N and P removal. We will then apply these reactors to treat actual agricultural runoff to examine the feasibility of this approach (Activity 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?

The specific project outcome is the algal bioreactor system for N and P removal. By applying these bioreactors to the field, we will be able to remove N and P from environments, thereby contributing to the improved water quality.

Activities and Milestones

Activity 1: Develop laboratory-scale nitrogen and phosphorus removing algal granule bioreactors

Activity Budget: $103,000

Activity Description:
Three laboratory-scale bioreactors will be designed and operated to develop the most efficient N- and P-removing algal granules. Synthetic agricultural runoff water with known amounts of N and P will be used in Activity 1 for the stable operation of the reactors. The size and density of the granules, as well as N and P removal rates, will be measured to evaluate the overall efficiency of the reactors. The reactor will be operated under cold conditions (5-10C) to simulate the field conditions. The reactor operation conditions (e.g., flow rate) will be optimized to maximize the granule size and N and P removal rates. Our target N removal rate is >80%. The algal and microbial community structures of the granules will be identified by using next-generation sequencing technology.

Activity Milestones:

Description	Completion Date
Development of N- and P-removing algal granules	June 30 2023
Identification of the algal and microbial community structures in the algal granules	December 31 2023
N&P removal rates of the algal granule bioreactor fed with synthetic agricultural runoff	December 31 2023

Activity 2: Apply algal granule bioreactors to clean agricultural runoff water

Activity Budget: $97,000

Activity Description:
Once we develop algal granule bioreactors for N and P removal, we will feed actual agricultural runoff water to the reactors. We will collect several agricultural runoff water samples with various N and P concentrations from different locations across the state. The stable operation of the reactors will be evaluated by the granule size and the N and P removal efficiency. If necessary, reactor operation conditions will be optimized. The cost and benefit of the algal bioreactor system will be evaluated by calculating the dollar amount necessary to remove N and P ($/lb N or P).

Activity Milestones:

Description	Completion Date
Stable operation of algal granule bioreactors with agricultural runoff water	June 30 2024
N&P removal rates of the algal granule bioreactors fed with actual agricultural runoff	June 30 2024
Dollar amount necessary to remove N and P ($/lb N or P)	June 30 2024

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 long-term goal of this research is to improve water quality by reducing N and P concentrations in agricultural runoff. The proposed project is the initial step (phase 1) of a three-phase project to achieve this goal. In the phase 2 project, multiple algal bioreactors will be installed and operated in the fields. In the third phase, we will develop low-cost bioreactors (<$1,000) to promote the installation of the algae bioreactors in the fields. Phase 2 and 3 projects will be done to maximize the impacts of this LCCMR-funded phase 1 project, with support from other funding.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Assessment of Water Quality for Reuse	M.L. 2017, Chp. 96, Sec. 2, Subd. 04f	$148,000

Project Manager and Organization Qualifications

Project Manager Name: Satoshi Ishii

Job Title: Associate Professor

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

Satoshi Ishii is Associate Professor in the BioTechnology Institute (BTI) and the Department of Soil, Water, and Climate (SWC) at the University of Minnesota. Dr. Ishii's research focuses on environmental microbiology and biotechnology, including water quality and public health microbiology. He has over 15 years of experience working on nutrient pollution in water environments including nutrient removal from wastewater and agricultural runoff.

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

Organization Description:

The University of Minnesota is the main research and graduate teaching institution in the state of Minnesota. The BioTechnology Institute provides advanced research, training, and university-industry interaction in biological process technology. In the Department of Soil, Water, and Climate, we seek to improve and protect the quality of soil, air, and water resources in natural and managed ecosystems, through research, teaching, and extension.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Professor		Project supervision, supervision of a post-doctoral researcher, project reporting.			27%	0.16		$31,000
Postdoctoral research associate		Collect samples, perform lab experiments, and analyze data for Activities 1 and 2; write reports			20%	2		$122,000
2 Undergraduate research technicians		Sample collection and processing, water quality analysis for Activity 1 and 2			0%	0.78		$20,000
							Sub Total	**$173,000**
Contracts and Services								
University of Minnesota Genomics Center	Internal services or fees (uncommon)	Next-generation sequencing to characterize microbial communities (approx. $30/sample x 100 samples)				0		$3,000
							Sub Total	**$3,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Lab-scale bioreactors including pumps and tubings ($3,000/each x 3 reactors)	Necessary to develop algal granules for N and P removal					$9,000
	Tools and Supplies	Lab supplies: chemicals and reagents for water quality testing and microbial analyses, glassware, and plastic and other consumables (gloves, tubes, plates, pipette tips, etc.) ($6,000/year x 2 years).	Necessary to analyze water quality (N and P concentrations) and identify algae and microbes important for the nutrient removal.					$12,000
							Sub Total	**$21,000**
Capital Expenditures								
							Sub Total	**-**

Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	In-state travel to collect water samples (Approximately 1740 miles at $0.575/mile per U of M travel policy)	Necessary to collect water samples from different agricultural areas in Minnesota					$1,000
							Sub Total	**$1,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Open access publication fee	Necessary to make the results publicly available					$2,000
							Sub Total	**$2,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$200,000**

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	University of Minnesota	The University of Minnesota is not allowed to charge the State of Minnesota its typical overhead rate of 55% of the total modified direct costs. We are listing our unrecoverable indirect cost as in-kind contribution.	Secured	$110,000
			State Sub Total	**$110,000**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**$110,000**

Attachments

Required Attachments

Visual Component

File: c17d4645-d0f.pdf

Alternate Text for Visual Component

This graphic shows how algal granule bioreactors developed in this project can reduce N and P concentrations in agricultural runoff to improve water quality in Minnesota....

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

Our overall goal

Current situation

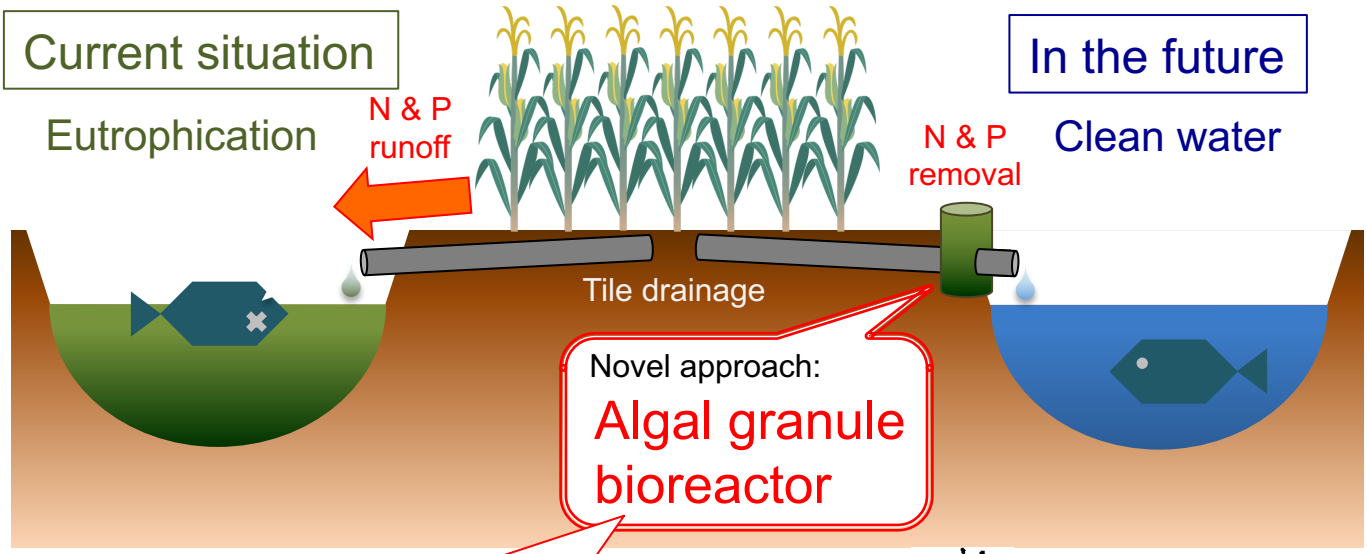
Eutrophication

N & P runoff

In the future

Clean water

N & P removal

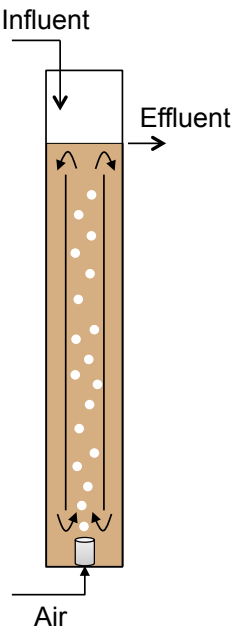


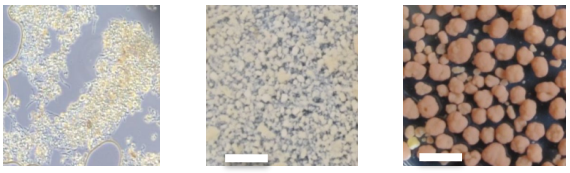
Novel approach:

Algal granule bioreactor

We can develop N&P-removing algal granules in reactor conditions!

Microbial granules for the N removal from wastewater (Song, Ishii, et al., 2013)

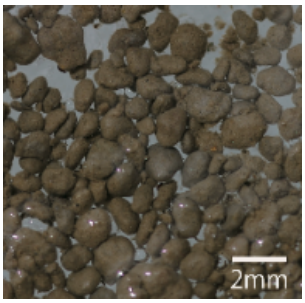


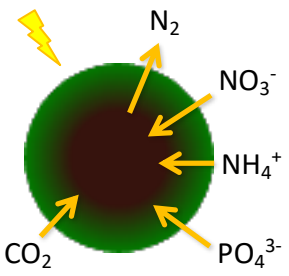


Development of the microbial granules

Naturally occurring algal granules found on a glacier can remove N & P

(Segawa, Ishii, et al., 2014; Segawa et al. 2020)





Previous achievements:

Song, Y., S. Ishii, et al. 2013. Development and characterization of the partial nitrification aerobic granules in a sequencing batch airlift reactor. Bioresour. Technol. 139:285–291.

Segawa S, Ishii S, et al. 2014. The nitrogen cycle in cryoconites: naturally occurring nitrification-denitrification granules on a glacier. Environ. Microbiol. 16: 3250-3262.

Segawa S, … and Ishii S. 2020. Redox stratification within cryoconite granules influences the nitrogen cycle on glaciers. FEMS Microbiol. Ecol. 96: fiaa199