

**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. Ineli gible** | **% Bene fits** | **# FTE** | **Class ified 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](https://lccmrprojectmgmt.leg.mn/media/map/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