Environment and Natural Resources Trust Fund
2019 Request for Proposals (RFP)

Project Title: **ENRTF ID: 065-B**

Outstate Wastewater: Low-Cost and Efficient Nutrient Removal Technology

Category: B. Water Resources

Sub-Category:

Total Project Budget: $ 275,000

Proposed Project Time Period for the Funding Requested: June 30, 2022 (3 yrs)

Summary:

This project will develop an innovative wastewater treatment technology for low-cost and highly efficient nutrient removal. This technology is particularly suitable for the treatment of outstate wastewater.

Name: Satoshi Ishii

Sponsoring Organization: U of MN

Title: Assistant Professor

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

This visual shows a diagram of the innovative wastewater treatment technology (=granular sludge technology) for simultaneous removals of nitrogen, phosphorus, and organic carbon.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%
____ If under $200,000, waive presentation?			

PROJECT TITLE: Outstate Wastewater: Low-cost and Efficient Nutrient Removal Technology

I. PROJECT STATEMENT

The overall goal of this project is to improve water quality by reducing nutrient loading from outstate wastewater. This goal will be achieved by developing an *innovative* wastewater treatment technology for low-cost and highly efficient nutrient removal. This technology innovation will lead significant decrease in nutrient loading from outstate wastewater, thereby improving Minnesota's water quality, stabilizing ecosystems, preserving biodiversity, and reducing public health.

Contamination of rivers and lakes with inorganic nutrients such as nitrogen (N) and phosphorus (P) can cause eutrophication, resulting in harmful algal blooms and fish kills. In addition, ammonia (NH_3) is toxic to aquatic life, and nitrate (NO_3^-) uptake can cause human diseases such as blue baby syndrome. To mitigate these problems, Minnesota Pollution Control Agency (MPCA) has targeted a goal of 45% reduction for N and P exiting the state by year 2040. While agriculture is considered as the major contributor of nutrient contamination, wastewater treatment plants (WWTPs) also discharge relatively large amount of nutrients. Reduction of P has been implemented in many WWTPs, but large amount of nitrate-N is still released to the environment. System upgrade for WWTPs can be costly, especially for outstate WWTPs. Therefore, technology innovation is necessary to remove nutrients from wastewater in high efficiency, while keeping building and operating cost minimal.

This project proposes to use novel granular sludge technology to simultaneously remove N, P, and organic carbon in a single aeration tank (see attached figure). Granular sludge are large, densely packed aggregates of microorganisms including ammonia oxidizing bacteria, denitrifying bacteria, and P accumulating bacteria. These microorganisms break down organic carbon and convert ammonia to nitrate, and then to harmless nitrogen gas (N_2). P is accumulated inside the bacterial cells, and removed by sludge discharge.

This technology is particularly suitable for outstate WWTPs because (1) it has high N and P removal efficiencies; (2) it requires less energy (= less cost) than conventional WWTP treatment systems; and (3) it does not require large space for biomass settling. To implement this technology into practice, we need to optimize the reactor operating conditions depending on the nutrient load. Both experimental and modeling approaches will be used to achieve this goal.

Therefore, the specific objectives of this research is to:

1. Develop laboratory-scale granular sludge bioreactors to simultaneously remove N, P, and organic carbon (Activity 1)
2. Generate and validate a model to optimize nutrient removal efficiencies (Activity 2)
3. Disseminate results to stakeholders (Activity 3)

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Reactor development

Two laboratory-scale bioreactors will be designed and operated to develop granular sludge for nutrient removal. The bioreactors will be fed with synthetic wastewater and operated under field-simulated conditions. Water samples will be collected to measure N and P removal efficiencies. Biomass samples will be also collected, and the size, density, and microbial community structure will be measured to analyze the stability of the granular sludge. Presence of microbes responsible in nutrient removals will be confirmed by high throughput DNA sequencing analysis. We target to produce effluent water quality of <10 mg-N/L and <1 mg-P/L to meet the MPCA's 45% nutrient reduction goal.

ENRTF BUDGET: $125,000

Outcome	Completion Date
1. Development of the granular sludge for nutrient removal	*June 2020*
2. Effluent water quality of <10 mg-N/L and <1 mg-P/L	*June 2021*

Activity 2: Model development and validation

The reactors will be operated under various nutrient-loading rates. Airflow rate, hydraulic retention time (HRT), and sludge volume will be adjusted to achieve effluent water quality of <10 mg-N/L and <1 mg-P/L. Based on the experimental data, we will generate a model to optimize the reactor operating conditions (airflow rate, HRT, and sludge volume) to produce high quality effluent water.

In addition, the reactors will be operated with actual wastewater samples with the conditions predicted by the model. Water quality will be monitored to evaluate the usefulness of the model.

ENRTF BUDGET: $145,500

Outcome	Completion Date
1. A model to optimize the reactor operating conditions	*June 2022*

Activity 3: Dissemination of the results

We will present the results at in-state scientific conferences and outreach events. We will also meet with stakeholders to disseminate results.

ENRTF BUDGET: $4,500

Outcome	Completion Date
1. Presentations at in-state scientific conferences and outreach events	*June 2022*
2. Meetings with stakeholders to disseminate results	*June 2022*

III. PROJECT PARTNERS:

This project will be led by Dr. Satoshi Ishii (Assistant Professor, BioTechnology Institute and Department of Soil, Water, and Climate, the University of Minnesota). One graduate research assistant and several undergraduate research assistants will be hired in this project.

This project is part of a larger research agenda at the University of Minnesota on the development and evaluation of treatment technologies for water and wastewater. We will coordinate with other U of M researchers to maximize the efficiencies and benefits from this project.

IV. LONG-TERM- IMPLEMENTATION AND FUNDING:

The long-term goal of this research is to improve water quality by reducing nutrient loading from outstate wastewater. The proposed project is the initial step (phase 1) of a three-phase project to achieve this goal. In the phase 2 project, pilot scale bioreactors will be installed on site to treat actual outstate wastewater. Economic analysis will be done at this phage. The third phase is the installation of full-scale bioreactors.

This research is *timely* and *important* because many of the Minnesota's outstate WWTP are getting old and need to be replaced or upgraded. That means, Minnesota has a great opportunity to implement new innovative technology into practice to improve water quality.

V. TIME LINE REQUIREMENTS:

We expect to complete the proposed project in 3 years: Activity 1 from July 2019 to June 2021; Activity 2 from July 2020 to June 2022; Activity 3 from July 2021 to June 2022.

2019 Proposal Budget Spreadsheet

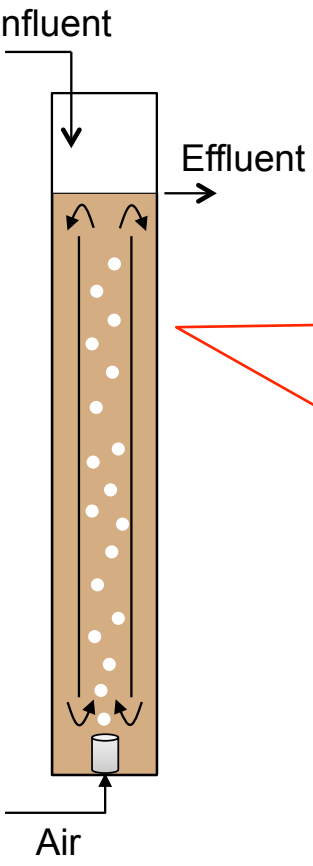
Project Title: *Outstate Wastewater: Low-cost and Efficient Nutrient Removal Technology*

IV. TOTAL ENRTF REQUEST BUDGET *3* **years**

BUDGET ITEM	AMOUNT
Personnel:	
Satoshi Ishii, Assistant Professor (75% salary, 25% benefits); 8% FTE for three years; overall project supervision, supervision of graduate and undergraduate students, project reporting.	$ 42,000
Graduate research assistant (55% salary, 45% benefits); 50% FTE for three years; perform Activity #1, #2, and #3 experiments, analyze data, write manuscripts	$ 139,000
Undergraduate research assistant (100% salary, 0% benefits); 100% FTE in summer for 5 months, 25% FTE during academic year for 27 months; perform Activity #1 and #2 experiments, analyze data	$ 21,000
Professional/Technical/Service Contracts: University of Minnesota Genomics Center: Microbial community analysis ($3,000/run x 2 runs); Nitrogen cycle evaluation chip ($1,000/run x 4 runs = $4,000)	$ 10,000
Equipment/Tools/Supplies:	
Bioreactors ($5,000 x 2)	$ 10,000
Water quality analysis ($20/sample x 1,500 samples = $30,000)	$ 30,000
DNA extraction ($5/sample x 200 samples)	$ 1,000
PCR reagents ($10/sample x 200 samples)	$ 2,000
Chemicals and reagents (culture media, chemicals, etc)	$ 5,000
Glassware and plastic consumables (pipette tips, filters, etc)	$ 5,000
Travel: In-state travel to collect samples and to present results to stakeholders	$ 5,000
Additional Budget Items: Publication charges to open access journals	$ 5,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 275,000

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:	N/A	
Other State $ To Be Applied To Project During Project Period:	N/A	
In-kind Services To Be Applied To Project During Project Period: The University of Minnesota does not charge the State of Minnesota its typical overhead rate of 54% of the total modified direct costs (graduate tuition and academic fringe are excluded).	$ 122,000	*Secured*
Past and Current ENRTF Appropriation:	N/A	
Other Funding History:	N/A	



Granular sludge = Large, densely packed aggregates of microorganisms

Granular Sludge Technology

→ Simultaneous N, P, and C removals
→ Suitable for outstate wastewater treatment

(1) High biomass density → High nutrient removal efficiencies
(2) High aeration efficiency → Low energy & cost for operation
(3) Small footprint → Low cost for construction

- Currently, Minnesota has a great opportunity to implement new *innovative technology* into practice to improve water quality.
- The proposed research will help implement this technology into practice by using both experimental and modeling approaches.

PROJECT TITLE: Outstate Wastewater: Low-cost and Efficient Nutrient Removal Technology

Project Manager Qualifications and Organization Descriptions

Satoshi Ishii, Ph.D.

Satoshi Ishii is Assistant Professor in the BioTechnology Institute (BTI) and the Department of Soil, Water, and Climate (SWC) at the University of Minnesota (U of M). He joined the BTI and SWC in April, 2015. He is also a faculty member of the Civil Engineering (CivE) and Water Resources Sciences (WRS) graduate programs. Prior to joining the U of M, he was Assistant Professor in the Division of Environmental Engineering in Hokkaido University, Japan, and a postdoctoral research associate in the University of Tokyo, Japan. He received his B.S. from the University of Tokyo, Japan, M.S. from Iowa State University, and Ph.D. from the U of M. His research focuses on environmental microbiology and biotechnology.

He has over 15 years of experiences on water quality microbiology. He has worked on nutrient removal from wastewater and agricultural runoff water. In addition, he has extensive experience on microbial aggregates in both natural and engineered systems.

Organization Descriptions

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, reaching, and extension.