Environment and Natural Resources Trust Fund
2015 Request for Proposals (RFP)

Project Title: **ENRTF ID: 040-B**

Woodchip Bioreactors Controling Sulfate, Nitrate, and Phosphorus Runoff

Category: B. Water Resources

Total Project Budget: $ 638,000

Proposed Project Time Period for the Funding Requested: 3 years, July 2015 - June 2018

Summary:

This project aims to enhance the efficiency of field-level woodchip bioreactors for reduction of nitrogen, phosphorus, and sulfate in agricultural drainage and sulfate in mine drainage by using optimal microorganisms

Name: Michael Sadowsky

Sponsoring Organization: U of MN

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Web Address

Location

Region: SE

County Name: Dodge, Rice

City / Township:

Alternate Text for Visual:

Map and Project Description

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage		_____ TOTAL

PROJECT TITLE: Woodchip bioreactors to control sulfate, nitrate, and phosphorus run-off in mining and agriculture

I. PROJECT STATEMENT

Passive biological reactors are a cost-efficient and effective method for reducing nutrients in drainage water before it is released to surface waters. The bioreactor is a subsurface trench filled with a carbon source (commonly woodchips) through which the drainage water is allowed to flow. The woodchips constitute the carbon source and biofilm surface for the development of a microbial community which reduces the load of various contaminants. While this technology has been applied to reduce levels of nitrate in field run-off, little is known about how this system works and how to optimize its use and efficiency for a variety of purposes. This project aims to evaluate the efficacy and enhance the efficiency of field-level bioreactors for the reduction of nutrients (particularly nitrogen; N and phosphorus; P) in agricultural drainage and sulfate (SO_4) in mine drainage and to improve their performance through enhancement by adding microbes and in bioreactor operation.

In Minnesota, subsurface drainage is a major pathway of transporting contaminants from land to surface water, which has significant environmental impact. For example, loss of nutrients from agricultural drainage to water systems has been of concern to human health and a major contributor to eutrophication of aquatic ecosystems. Consequently, the USEPA has called for a 45% minimum reduction in total nitrogen loading to the Mississippi River. Likewise, sulfate drainage from mining operations in Northern Minnesota is correlated with methyl mercury contamination in water bodies and has a negative impact on wild-rice and acid levels of adjacent waterways. Thus, for protection and restoration of the MN's water resources, it is essential to reduce the level of N, P, and sulfate contaminants in subsurface drainage in a cost-effective and efficient manner.

While among proposed water quality improvement strategies, passive woodchip bioreactors can be very cost effective, the performance of these bioreactors tested in Minnesota, and elsewhere is still limited and highly variable. This is in large part due to our ignorance of the microbial ecology of the bioreactor system, and our understanding of the functioning and activity of the requisite microbes involved in nutrient removal. In this project, we will characterize the total microbial community and assess relative abundances of taxa associated with nutrient removal in existing field bioreactors implemented in Minnesota using metagenomic DNA sequencing approaches. Based on this characterization, we will enhance the microbial communities responsible for nutrient reduction within the bioreactors through the introduction of optimal species or environmental management for improved bioreactor performance. This project develops novel strategies to enhance the effectiveness of agricultural and mining practices by mitigating off-site movement of contaminants in Minnesota.

These studies will put Minnesota at the forefront of this important area of environmental research. Project outcomes will provide more insight into increasing the efficacy of contaminant removal strategies for mining and agricultural practices with the ultimate goal of improving water quality, while allowing for important economic activities. We also believe that one of the best approaches to protect and restore water resources in Minnesota is to engage the public through exhibits at the Science Museum of Minnesota and the Bell Museum of Natural History.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Denitrification Bioreactor for Agricultural Drainage — Budget: $379,000

We will modify and enhance the performance of existing woodchip bioreactors installed in two locations in MN: Claremont in Dodge county and Dundas in Rice County for load reduction of N and P nutrients in agricultural drainage (see the attached map). These bioreactors, monitored during 2010-2011, reduced the annual load of N by only 28% at peak flow rates and the reduction varied seasonally, suggesting that flexible and optimal operation using engineering and microbiological principals may be needed for the performance enhancement. We will characterize spatial distribution of microbial communities, both vertically and horizontally, throughout the bioreactor in growing and snowmelt seasons using a 16S rDNA-metagenomic-based sequencing technique. Concurrently, we will monitor nutrients and physiochemical parameters in each bioreactor using sensors and continuous water sampling and key functional microbial activities involved in N and P cycling by using quantitative PCR techniques. This will allow for the identification and relative quantification of microbial species responsible for N and P reduction in bioreactors. Based on this characterization, we will inoculate optimal species or mixed cultures enriched from the bioreactors and/or introduce soluble carbon sources (acetate, starch) to

enhance bioreactor performance, and assess the effect of the treatment by monitoring nutrient reduction performance and microbial activities.

Outcome	Completion Date
1. Sample collection and performance monitoring.	October 31, 2017
2. Identify and quantify microbial community in the bioreactors.	December 31, 2017
3. Determine the effect of augmenting microbial species on the bioreactor performance.	April 30, 2018

Activity 2: Sulfate-Reducing Bioreactor forMining Drainage **Budget: $232,000**

While most studies of woodchip bioreactors have focused on N and P nutrients, a properly tuned bioreactor will also be efficacious in removing sulfate – an emerging contaminant associated with mining activities. We will use the facility and bioreactor at Morris West Central Research and Outreach Center of the University of Minnesota as an experimental demonstration site for sulfate reduction in mining drainage. We previously monitored sulfate and methyl mercury in the denitrifying bioreactor. In this project, we will focus on sulfate-reducing performance of the bioreactor for mining drainage. The source of water will be from a well inside the center facility and be modified to approximate sulfate-rich mining wastewater. We will examine sulfate reduction performance and microbial communities on a vertical and horizontal grid throughout the bioreactor, with and without augmenting with optimal sulfate-reducing species, in the similar manner with Activity 1. Several physiochemical parameters and methylation of mercury will be monitored concurrently. As above, reactors will be augmented with sulfate-reducing bacteria and iron to enhance sulfate reduction and removal.

Outcome	Completion Date
1. Sample collection and performance monitoring	October 31, 2017
2. Identify and quantify microbial community in the bioreactors	December 31, 2017
3. Determine the effect of augmenting optimal species on the bioreactors' performance	April 30, 2018

Activity 3: Project data dissemination **Budget: $27,000**

In this result, we will disseminate our results through personal presentations, fact sheets, and papers in peer reviewed professional journals. Moreover, we will develop a practical-oriented document to help landowners and professionals in the field understand, manage, and monitor their bioreactors for subsurface drainage. We will also develop public displays at museums to reach a large number of adults and children for water conservation.

Outcome	Completion Date
1. Production of public exhibits.	December 31, 2017
2. Dissemination of project data and results via seminars, and workshops.	June 30, 2018

III. PROJECT STRATEGY

A. Project Team/Partners

The project will be carried out under the direction of Drs. Michael Sadowsky (PI), Carl Rosen, Chanlan Chun. Together they will direct Research Associate Andry Ranaivoson. Funded project partners will include Pat Hamilton of the Science Museum of Minnesota, and Susan Weller, Bell Museum Director. We will also collaborate with Barb Peichel at MPCA and Heidi Peterson at MDA for dissemination activities.

B. Project Impact and Long-Term Strategy

This request seeks funding for the first 3 years of this program. This will provide key information on the effectiveness of enhanced bioreactor performance in reducing nitrate, sulfate, and phosphorus loading of drainage to surface waters in Minnesota. Additional funding for more long term and more extensive operation will be obtained from grants applied for to the USDA, mining industries, UMN, and other agencies.

C. Timeline Requirements

The project will be completed over a period of 36 months including two complete field seasons (March-November in 2016 and 2017), but the impact will last for many more. Multiple years of sampling and analysis are required for adequate, reliable data and multiple years are required for effective incorporation into public education venues.

2015 Detailed Project Budget

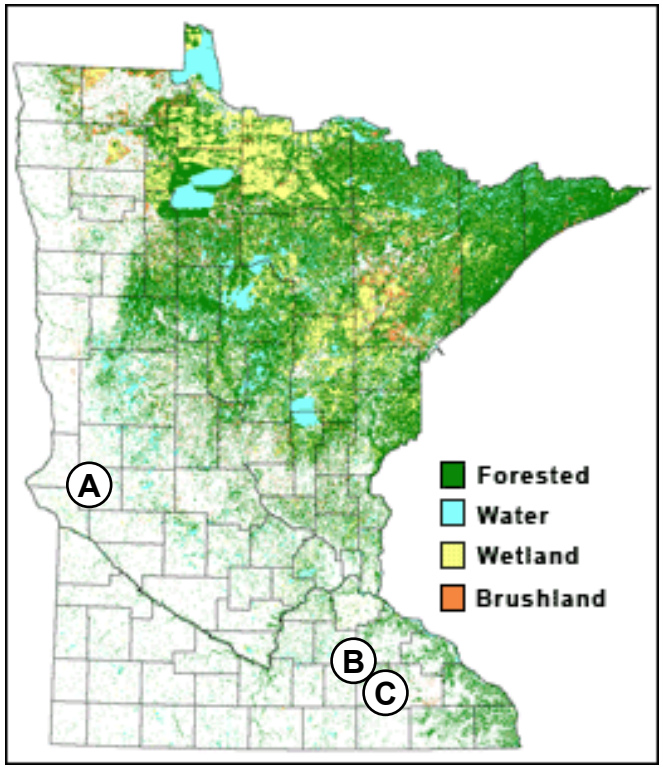
Project Title : Woodchip bioreactors to control sulfate, nitrate, and phosphorus run-off in mining and agriculture

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

BUDGET ITEM	AMOUNT
Personnel:	
Chanlan Chun:Research Associate ($44,290, 16% time, 34% fringe, 3 years, 1 person)	$ 30,000
Andry Ravaivoson:Research Associate ($44,290, 16% time, 34% fringe, 3 years, 1 person)	$ 30,000
Postdoctoral Associate ($41,000, 100% time, 20.75% fringe, 3 years, 1 person)	$ 152,000
Graduate Student (50% time, 37% tuition, 9 % fringe, 3 years, 1 person)	$ 116,000
Technician (24% time, 36% fringe, 3 years, 1 person)	$ 53,000
Contracts:	$ -
Exhibit at Science Museum of Minnesota and Bell Museum (staff time and materials)	$ 25,000
Equipment/Tools/Supplies:	$ -
Equipments for sample collection and performance monitoring	$ 48,000
Laboratory supplies: $20,000/year × 3 years	$ 60,000
Publication	$ 2,000
Acquisition (Fee Title or Permanent Easements): *In this column, indicate proposed number of acres*	$ -
Travel:.	$ -
In-state Travel for 24 samplings per year × 3 years @6000 mi × $0.50/mi	$ 3,000
Conferences	$ 2,000
Additional Budget Items: Sample analysis: 90 water and 50 woodchip samples: Genome preparation @$200/sample =$28,000, genome anlayisis= @$600/sample=$84,000, physiochemical analysis=$5,000). Genome preparation and all genomic analyses are done most cost effectively in specialty labs that charge by the sample	$ 117,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 638,000

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period: N/A	$ -	*Indicate: Secured or*
Other State $ To Be Applied To Project During Project Period: Denitrifying bioreactor mointoring performed by MDA Clean Water Project and MNDrive for Microbial Systems for Bioremediation will be used to leverage this project	$ 380,029	*Pending*
In-kind Services To Be Applied To Project During Project Period: *N/A*	$ -	*Indicate: Secured or*
Funding History: N/A		
Remaining $ From Current ENRTF Appropriation: N/A	$ -	*Indicate: Unspent? Legally*



Bioreactor sites:

A. **Morris West Central Research and Outreach Center**
B. **Dundas (East of Northfield) in Rice County**
C. **Claremont (East of Owatonna) in Dodge county**

Project Manager Qualifications and Organization Description:

Project Manager: Dr. Michael J. Sadowsky

Title: McKnight University Professor and Director BioTechnology Institute

Affiliation: University of Minnesota, Department of Soil, Water and Climate, and BioTechnology Institute

The UMN Biotechnology Institute (BTI) provides advanced research, training, and university-industry interactions in biological process technology, and other areas of biotechnology research. Faculty in the BTI have broad expertise in: Biocatalysis, Metabolic engineering/microbial physiology, Population dynamics, Molecular biology, Proteomics and focused expertise in defined areas such as bioremediation, biomaterials, biosensors, and bioinformatics.

Education:
Ph.D., 1983. University of Hawaii, Honolulu, Hawaii. Major: Microbiology
M.S., 1979. University of Wisconsin-Oshkosh, Wisconsin. Major: Microbiology
B.S, 1977. University of Wisconsin-Madison, Wisconsin. Major: Bacteriology

Professional Experience:
Director BioTechnology Institute, University of Minnesota, St. Paul, Minnesota, 2009 - present.
Co-Director, Microbial and Plant Genomics Institute, University. of Minnesota, 2006-2009.
Distinguished McKnight University Professor: Department of Soil, Water, & Climate, and BioTechnology Institute, University of Minnesota, St. Paul, Minnesota, 04/04 - present.
Professor: Department of Soil, Water, and Climate and Department of Microbiology
University of Minnesota, St. Paul, Minnesota, 07/96 – 04/04.
Associate Professor: Departments of Soil Science and Microbiology
University of Minnesota, St. Paul, Minnesota, 07/93 - 6/96.
Assistant Professor: Departments of Soil Science and Microbiology
University of Minnesota, St. Paul, Minnesota, 06/89 - 6/93.
Microbiologist: U.S. Department of Agriculture-ARS; Beltsville, Maryland, 01/86 - 05/89.

Dr. Sadowsky will have chief management responsibilities for overseeing the proposed project. He will be responsible for working with Drs. Carl Rosen, Chanlan Chun, and Andry Ranaivoson, and project partners to ensure that project goals, results and timelines are met. He will also be responsible for working with the undergraduates, and postdoctoral associate at UMN, and staff at museums. Dr. Sadowsky is an environmental microbiologist with 30 years research experience in the analysis and use of microorganisms in environmental settings. Dr. Sadowsky's laboratory studies the distribution and diversity of microorganisms in aquatic and soil environments and uses genetic, genomic, and biotechnology tools to examine how microorganism become established in new environments. He is currently Director of the BioTechnology Institute, and is currently involved in three large metagenome projects; the soil metagenome to define novel microbial genes for agriculture, biofuels and bioenergy; the Mississippi River metagenome project (M3P) that examines the impact of human activity on the diversity and function of microbes in the Mississippi River; and the Human Intestinal metegenome project that defines changes in human intestinal tract microbiota due to *Clostridium difficile* diarrheal disease and fecal transplantation.