Environment and Natural Resources Trust Fund
2020 Request for Proposals (RFP)

Project Title: **ENRTF ID: 225-F**

New Organic Fertilizer to Protect Minnesota's Water Quality

Category: F. Methods to Protect, Restore, and Enhance Land, Water, and Habitat

Sub-Category:

Total Project Budget: $ 499,000

Proposed Project Time Period for the Funding Requested: June 30, 2023 (3 yrs)

Summary:

This study will protect Minnesota's water quality by developing a slow-nutrient-release, organic fertilizer based on co-composting biochar with manure. Fertilizer production and application provide economic incentives for Minnesota's livestock farmers.

Name: Sebastian Behrens

Sponsoring Organization: U of MN

Job Title: Dr.

Department: Department of Civil, Environmental, and Geo-Engineering

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Minneapolis MN 55455

Telephone Number: (651) 756-9359

Email sbehrens@umn.edu

Web Address:

Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

The graphic shows a pile of mixed manure, three different charcoals, the Minnesota's States outlines on a Dollar bill, water running off an agricultural field and a bag of fertilizer.

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

PROJECT TITLE: New organic fertilizer to protect Minnesota's water quality

I. PROJECT STATEMENT

The objectives of this study are to protect the quality of Minnesota's precious surface and groundwater resources by developing a marketable, slow-nutrient-release fertilizer based on composting biochar together with manure, which will also help Minnesota's livestock farmers realize more value from their manure. According to the Minnesota Department of Health, farm-related nitrate pollution represents a growing threat to Minnesota's drinking water. Nitrate comes from many sources, including manure, septic systems, and natural decomposition of organic matter. Fertilizers applied to land used for crop production have the biggest influence on Minnesota's ground and surface water nitrate levels. Recently, our research has provided evidence that *co-composting of farm manure and biochar* has positive effects on plant growth, carbon mineralization, nutrient capture, and retention. Converting abundant agricultural residues, such as green waste and manure, to valuable products, such as biochar and organic fertilizer, can create a new profitable market and revenue for Minnesota livestock farmers. **This proposed project will provide Minnesota's livestock farmers and the Minnesota Pollution Control Agency with information on a new innovative treatment process for manure management which will help the State to protect its surface water quality.**

Biochars are an abundant end product of the biomass energy industry. Converting woody biomass and agricultural byproducts into renewable biofuels leaves behind a carbon-rich material similar to charcoal (called biochar). Our research has recently shown that addition of these chars to waste treatment processes such as composting, reduces the losses of nitrogen and phosphorous from the compost mixture creating a well-stabilized product that can be beneficial to agriculture. For example, biochars co-composted with mixed manures have been shown to be effective in adsorbing and retaining manure nutrients (such as nitrate and phosphate) preventing nutrient leaching and runoff when applied to the field. **We propose that biochars can be used to capture nutrients from manure to create a sustainable, slow-release organic fertilizer that has an increased market value, can be transported, and effectively applied to the field. The new organic fertilizer will protect Minnesota's water quality and help Minnesota livestock farmer to better manage manure nutrient application and to realize more value from their manure for crop production.** Besides nutrient management, the application of biochar as an additive to manure storage structures and composting facilities also offers other benefits, such as increased carbon storage in soils and reduced odor emissions during manure handling. The composting process (degradation of organic matter at temperatures up to 70°C) can help to reduce the load of pathogenic bacteria and antibiotic resistant genes in the manure prior to field application. **The process of co-composting manure with biochar has the potential to significantly save costs for nitrogen and phosphorous fertilizer application and reduce the environmental consequences of excess nutrient leaching and runoff into Minnesota's waterways.**

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1 Title: Production and characterization of biochar-amended manure compost (BMC) to protect MN water quality

Description: There are a range of practical things we need to understand when adding biochar during the manure composting process (amounts needed, best types of biochar/manure to use, does the compost or biochar need to be shredded first, etc.). This will help optimize the process and provide the highest-quality product. In this activity we will produce different biochar-blended composts and study their nutrient retention properties in order to lower nutrient run-off from fields after manure application. **ENRTF BUDGET: $ 173,735**

Outcome	Completion Date
1. Production of four different biochar blended composts (2 chars + 2 manure types)	*March 31, 2021*
2. Determine the optimal doses, biochar feedstock and particle size	*August 31, 2021*
3. Quantification of nutrient retention and water quality impacts of biochar-manure compost fertilizer	*June 30, 2022*

Activity 2 Title: Nutrient cycling and storage in biochar-amended manure compost. Monitoring of antibiotic resistance gene and microbial pathogen loads for water quality protection.
Description: Microorganisms play a key role in the composting process, nutrient capture and release. We will study the interaction of biochar with the soil microbiome and key nutrient cycling processes taking place during composting and after compost field application (biodegradation, gas emissions, nutrient transformation, etc). We will quantify antibiotic resistant genes and microbial pathogens in the manure before and after composting to better control their environmental impact on Minnesota's water quality after manure field application.
ENRTF BUDGET: $ 208,801

Outcome	Completion Date
1. Genomic analysis of microbial nutrient cycling processes in biochar blended composts	*July 31, 2022*
2. Quantification of antibiotic resistance in manure and compost (before & after composting) for water quality protection	*December 31, 2022*
3. Quantification of loads of microbial pathogens in manure and compost (before & after composting) for water quality protection	*December 31, 2022*

Activity 3 Title: Field trials and cost-benefit analysis
Description: The production, distribution, and application of biochar-amended manure compost requires a comprehensive understanding of the challenges associated with using manure as a fertilizer. To understand whether integration of biochar into commercial manure composting operations is viable, we will conduct full-scale field experiments and a life-cycle cost-benefit analysis. In this activity we will also explore the monetary value of co-composting manure with biochars for farmers in Minnesota and disseminate our results at local conferences and through scientific publications. **ENRTF BUDGET: $ 116,464**

Outcome	Completion Date
1. Measure long-term performance and nutrient slow-release in field experiments	*July 31, 2023*
2. Perform cost-benefit analysis on the livestock-energy-nutrient-management life-cycle and benefits for Minnesota's water quality	*July 31, 2023*
3. Publication in scientific journals and presentation of results at State conferences	*July 31, 2023*

III. PROJECT PARTNERS AND COLLABORATORS:

The project team will be led by Drs. Sebastian Behrens (Dept. of Civil, Environmental, and Geo-Engineering, University of Minnesota) and Dr. Melissa Wilson (Dept. of Soil, Water, and Climate). Behrens is an expert on soil-biochar nutrient cycling and Wilson is an expert on manure handling techniques and farming practices that reduce impacts on water quality. The proposed research will be conducted in collaboration with Dr. Timothy LaPara (Dept. of CEGE), an expert on the environmental fate of antibiotic resistance markers. The team also will include one post-doctoral research associate, a graduate student, and a field technician.

IV. LONG-TERM IMPLEMENTATION AND FUNDING:

Results of the proposed research will be shared with the Minnesota Pollution Control Agency (MPCA) to inform the development of new rules that govern the collection, transportation, storage, processing, and land application of animal manure for water quality protection. This project will **develop economic incentives for Minnesota's livestock farmers while protecting Minnesota's water resources and pristine aquatic ecosystems from excess nutrient pollution.**

V. SEE ADDITIONAL PROPOSAL COMPONENTS: A. Proposal Budget Spreadsheet

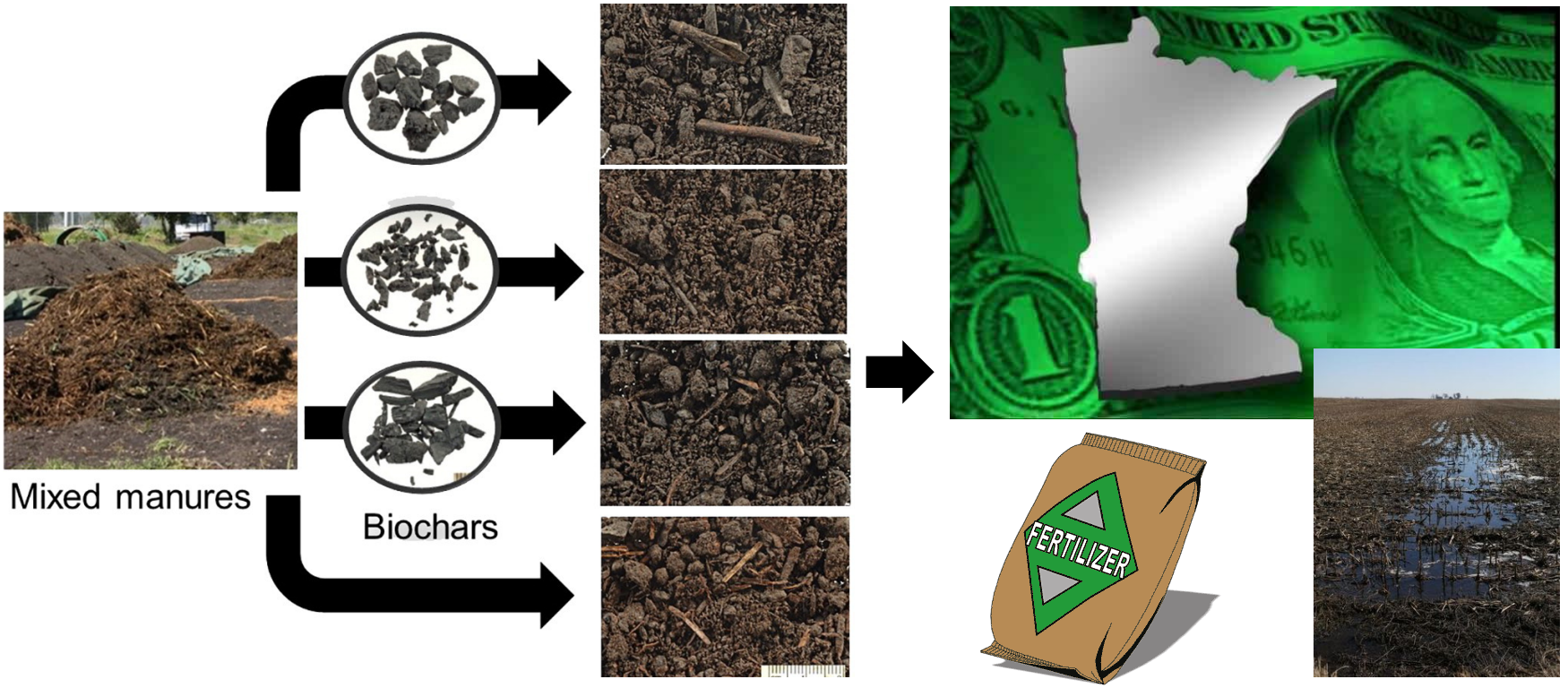
Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Sebastian Behrens
Project Title: New organic fertilizer to protect Minnesota's water quality
Organization: University of Minnesota
Project Budget: $499,000
Project Length and Completion Date: 3 years, ending June 30, 2023
Today's Date: April 08, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 409,000	$ -	$ 409,000
Dr. Sebastian Behrens, Project Manager (74% salary, 26% fringe) 8% FTE for each of the 3 years			
Dr. Melissa Wilson, Co-PI (74% salary, 26% fringe) 6% FTE for each of the 3 years			
Dr. Timothy LaPara, Co-PI (74% salary, 26% fringe) 3% FTE for each of the 3 years			
Postdoctoral Research (TBD) (80% salary, 20% fringe) 100% FTE for each of the 2 years			
Two Graduate students (TBD) (58% salary, 42% tuition and fringe) 50% FTE for each of the 2 years			
Field technician (TBD) (77% salary, 23% fringe) 50% FTE for each of the 1 years			
Professional/Technical/Service Contracts	$ 20,000	$ -	$ 20,000
University of Minnesota Genomics Center: DNA sequencing, quantitative PCR; Research plot fees			
Equipment/Tools/Supplies	$ 55,000	$ -	$ 55,000
Research Analytical Laboratory at the University of Minnesota - Inorganic chemical analyses for water, soil, biochar - Ion chromatography and Flow Injection Analysis: ammonia, nitrate, nitrite, phosphorus, Total C/Total N Analysis: TOC, TIC, TN, ICP-OES etc ($10K); Consumables and chemicals, gases, plastic ware and reagents and fees for molecular biology experiments (DNA extraction/DNA sequencing; quantitative PCR at University of Minnesota Genomics Center) ($15K per year to share among postdoc, graduate student, and technician: total $45k)			
Printing	$ 6,000	$ -	$ 6,000
Scientific journal open-access publicaton fees ($2K for year 2; $4K for year 3)			
Travel expenses in Minnesota	$ 9,000	$ -	$ 9,000
In-state travel to field sites and local conferences for proposal personnel ($3K per year)			
	$ 499,000	$ -	$ 499,000
COLUMN TOTAL			

SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
		$ -	$ -	$ -
Non-State: N/A		$ -	$ -	$ -
State: N/A		$ -	$ -	$ -
In kind: In-kind Services To Be Applied To Project During Project Period: F&A costs for this project of 54% of total costs (not including grad student tuition) which cannot be budgeted for state awards	*secured*	235,000		235,000

Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	Amount legally obligated but not yet spent	Budget	Spent	Balance
		$ -	$ -	$ -
"Engineered biofilters for sulfate removal from mine waters" ML 2016, Chp 186 Sec 2 Subd 04p E816SMR		440,000	370,300	69,700

Environment and Natural Resources Trust Fund (ENRTF)
2020 Main Proposal VISUAL
Project Title: New organic fertilizer to protect Minnesota's water quality



Biochar Amended Manure Compost

Protecting Minnesota's Water Quality with a Slow-Release Organic Fertilizer

Hagemann et al. (2015) SOIL EN 613–614: 20–29. http://dx.doi.org/10.1016/j.scitotenv.2017.03.161
www.wdio.com/wdioimages/repository/2018-05/Minnesota-MN-Money.jpg

PROJECT MANAGER QUALIFICATIONS

SEBASTIAN F. BEHRENS

a. Professional Preparation.

Institution	Major	Degree	Year
University of Bremen, Germany	Biology	B.Sc.	1997
University of Bremen, Germany	Microbiology	M.Sc.	2000
MPI for Marine Microbiology, Germany	Microbial Ecology	Ph.D.	2003

b. Appointments.

Since 2015	Assoc. Professor, Civil, Environmental, and Geo-Engineering, University of Minnesota
2008-2014	Assistant Professor, Center for Applied Geosciences, University of Tuebingen, Germany
2004-2008	Postdoctoral Researcher, Civil and Environmental Engineering, Stanford University

c. Products.

RECENT PRODUCTS MOST CLOSELY RELATED TO THE PROJECT PROPOSAL

5. Hagemann N, Subdiaga E, Orsetti S, de la Rosa Arranzc JM, Knicker H, Schmidt HP, Kappler A, **Behrens S** (2018) Effect of biochar amendment on compost organic matter composition following aerobic compositing of manure. *Science of the Total Environment* 613-614: 20-29.

4. Hagemann N, Joseph S, Schmidt H-P, Kammann CI, Harter J, Borch T, Young RB, Varga K, Elliot KW, McKenna A, Chen H, Albu M, Mayrhofer C, Obst M, Conte P, Dieguez-Alonso A, **Behrens S**, Kappler A (2017) Organic coating on biochar explains its nutrient retention and stimulation of soil fertility. *Nature Communications* 8: 1089.

3. Archanjo B, Mitchell D, Achete C, **Behrens S**, Kappler A, Enders A, Munroe P, Hagemann N, Zwieten L, Mayerhofer C, Mai T, Horvat J, Mendoza M, Weng Z, Araujo J, Donne S, Joseph S, Albu M (2017) Nanoscale Analyses of the Surface Structure and Composition of Biochars Extracted from Compost and from Cultivated Fields Using Advanced Analytical Electron Microscopy. *Geoderma* 294: 70-79.

2. Hagemann N, Kammann CI, Schmidt H-P, Kappler A, **Behrens S** (2017) Nitrate capture and slow release in biochar amended compost and soil. *PLOS One* 12: e0171214.

1. Hagemann N, Harter J, Kaldamukova R, Guzman-Bustamante I, Ruser R, Graeff S, Kappler A, **Behrens S** (2016) Does soil aging affect the N_2O mitigation potential of biochar? A combined microcosm and field study. *GCB Bioenergy* DOI: 10.1111/gcbb.12390

d. Synergistic activities.

I follow an interdisciplinary approach that combines the disciplines environmental engineering, microbiology, and molecular biology to understand the basic ecological principles driving the bioremediation of metals, the biodegradation of organic contaminants, and the transport and fate of nutrient in the environment. The knowledge I gain by studying these processes in natural and engineered ecosystems I then apply to optimize remediation approaches, resource recovery, and the biological treatment of water, thereby spanning the gap between basic and applied research aspects of environmental management and restoration.

ORGANIZATION DESCRIPTION

The University of Minnesota is the State's main research and graduate teaching institution. The University partners with communities and governmental agencies across Minnesota to engage students, faculty, and staff in addressing society's most pressing issues. The Department of Civil, Environmental and Geo-Engineering focuses on collaborative and interdisciplinary research within critical areas such as managing and sustaining water and land-use infrastructure, mitigating disaster of the natural and built environments, engineering and developing earth resources, and designing renewable energy systems.