Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-453

Proposal Title: Engineered Soils for Pollution and Road Salt Resiliency

Project Manager Information

Name: Sebastian Behrens

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: Research will focus on the resilience of Minnesota's soils to stormwater pollutants and road salt stress with emphasis on the impacts of biochar on contaminant removal and overall soil health

ENRTF Funds Requested: $550,000

Proposed Project Completion: June 30, 2030

LCCMR Funding Category: Water (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?

During the Project and In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Urban stormwater runoff transports harmful contaminants to receiving soils, waters and aquatic ecosystems in Minnesota. Increased urbanization and severity of precipitation patterns are expected to heighten the threat of stormwater runoff contamination because of growth of urban impervious surface area and changes in the intensity of storm events. In addition, in temperate climates, extensive road salt application during the winter is needed to ensure road and pavement safety. However, the long-term application of road salts (and their additives) poses additional challenges for Minnesota's soils and water environments receiving stormwater runoff. Urban stormwater runoff contains a variety of contaminants ranging from traditional water quality indicators such as total suspended solids and turbidity to nutrients, pathogens, metals, and organic chemicals. Stormwater runoff is a significant mechanism for carrying metals such as cadmium, copper, lead, nickel, and zinc to receiving water bodies. Also, many trace organic contaminants are found in urban stormwater. Hydrophilic organic contaminants are of particular interest because of their mobility and ubiquitous presence (e.g. per- and polyfluoroalkyl substances). Effective treatment of stormwater runoff before it's entering Minnesota's soils and waters is therefore necessary for the protection of environmental and human health and the state's precious soil and freshwater resources

What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.

Stormwater control measures include grass swales, infiltration trenches, bioretention basins, and detention ponds. Black carbonaceous materials such as activated carbon and biochar have the potential to capture stormwater contaminants when integrated in existing stormwater control measures. However, it is unknown how these filtration media and soil additives perform under high-volume flow, especially in the presence of elevated salt concentrations during the winter. So far road salt pollution has not been considered in studies of water resource quality. This study will investigate the contaminant removal properties of engineered media mixtures under high-volume flow and varying salinity and will develop design guidelines for efficient high-throughput treatment of stormwater runoff. We will test the efficiency of biochar, activated carbon, sand, and zeolite in mixtures with Minnesota soils to remove a range of organic and inorganic stormwater contaminants in laboratory scale column studies. Particle size, flow, and salinity will be adjusted to facilitate the direct transfer of the findings to the field for effective year-round stormwater treatment in Minnesota. We will quantify the total impact of chlorides on physicochemical processes affecting contaminant sorption and release from various media mixtures and determine the resulting toxicity threat for biota and microbiological processes for receiving ecosystems

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 main outcome from this project will be a better understanding on how to engineer soils and stormwater infrastructure for pollution resistance and effective contaminant removal. Through optimizing the chemical, physical, and biological parameters of soils and filter media this project will provide design guidelines for stormwater control measures in Minnesota. The project will establish a baseline of information that municipalities, agencies, and state engineers can use to develop new and maintain and upgrade existing stormwater infrastructure to protect Minnesota's soils and waterways from the impacts of chlorides and stormwater contaminants

Activities and Milestones

Activity 1: Improved Engineered Filter Media for Contaminant Removal from Stormwater

Activity Budget: $185,000

Activity Description:
Treatment of high-volume, cold-climate flow with increased salinity requires enhancing the natural capacity of Minnesota's stormwater filters to sequester, degrade, and retain contaminants, especially in the winter months. In this activity we will study treatment of urban stormwater runoff using engineered media amendments to remove nutrients, organic and metallic contaminants. We will focus on biochar and activated carbon materials and use conventional amendments such as sand and aluminosilicate minerals (zeolite) as reference materials. Biochar is a stable, carbon-rich charcoal-like material produced by heating biomass in a low-oxygen environment in a process called pyrolysis. Biochar will be locally sourced from the City of Minneapolis new production facility. Biochar filter media mixtures will be optimized (e.g. volume, particle size) for effective contaminant removal kinetics at seasonally relevant flow rates. Additionally, we will investigate the effect of elevated sodium chloride concentrations on the filter's removal performance for individual contaminants. Investigating realistic flow rates, different biochar filter media composition, and the impact of increasing salt concentrations we will establish baseline data on filter performance and effectiveness. The outcomes from these laboratory column studies will allow us to determine critical design parameters for full scale implementation of biochar-amended stormwater treatment technologies

Activity Milestones:

Description	Approximate Completion Date
Sourcing local soils and biochar for filter media	December 31, 2027
Setup of laboratory column experiments	June 30, 2028
Batch sorption isotherm studies	June 30, 2029
Metal removal experiments	December 31, 2029
Organic contaminant removal experiments	December 31, 2029
Publication/dissemination	June 30, 2030

Activity 2: Mitigating the Impact of Road Salts on Soil Bioprocesses and Biodegradation of Stormwater Pollutants

Activity Budget: $185,000

Activity Description:
Road salts severely degrade soil health and disrupt soil biological processes and microbial communities, reducing their capacity to biodegrade pollutants in stormwater runoff. Elevated salinity reduces soil permeability by dispersing clay particles, inhibits nutrient cycling (nitrogen, carbon, phosphorus), and shifts microbial communities toward less diverse, functionally beneficial, and salt-tolerant species. This ecological shift decreases the efficiency of microbial degradation of organic pollutants, such as PAHs, and limits the ability of bioretention systems to filter contaminants. The aim of this activity is to assess if biochar amendment to soil and stormwater infrastructure can alleviate the threat posed by road salts on natural soil bioprocesses. We will run soil microcosm experiments at different salinity levels to determine microbial carbon, nitrogen, and phosphorus cycling activities and microbial community composition. We will quantify soil nutrient stoichiometry to see if the nutrient balance will support healthy soil communities, and we will use metagenomics to determine the functional resilience of microbial communities to be able to tolerate excess salt while continuing to process critical nutrients and detoxify pollutants. We will test the hypothesis that soil microbial bioprocesses will present better higher resistance to stormwater contaminants and elevated road salt concentrations in the presence of biochar

Activity Milestones:

Description	Approximate Completion Date
Batch experiments to assess impact of salinity on aerobic and anaerobic soil bioprocesses	June 30, 2029
Biodegradation of organic contaminants under high salinity stress	December 31, 2029
Resistance and biotransformation of heavy metals under high salinity stress	December 31, 2029
Metagenomic analysis to identify shifts in soil microbial community composition and function	December 31, 2029
Publication/dissemination	June 30, 2030

Activity 3: Activity and Reactivity of Pyrogenic Carbonaceous Matter toward Heavy Metals and Organic Contaminants

Activity Budget: $180,000

Activity Description:

Engineered carbons (e.g., biochar and activated carbon) are more than passive sorbents, adsorbing contaminants while also promoting chemical reactions on their surfaces. These reactions can alter the chemical form of metals and organic contaminants through processes such as redox transformations and hydrolysis, which may change contaminant mobility and toxicity. As a result, contaminants retained on biochar may not only be captured, but also transformed into less mobile, less harmful, or more hazardous forms.

However, the mechanisms controlling these reactions under environmentally relevant conditions, particularly in stormwater systems with elevated salt concentrations, remain poorly understood. To address this gap, biochar particles will be recovered from the experiments in Activities 1&2 and analyzed using high-resolution microscopy and spectroscopy. These analyses will enable spatially resolved geochemical mapping of metals and nutrients on biochar particles to determine where contaminants are retained within the biochar structure, including pore spaces and fractured surfaces that expose reactive sites. The analyses will also assess microbial biofilms and identify new chemical forms of contaminants that develop on biochar surfaces under different salinity conditions. Together, these measurements will provide insight into how biochar structure, surface chemistry, and microbial interactions influence contaminant retention and transformation in stormwater filtration systems

Activity Milestones:

Description	Approximate Completion Date
Sample collection	June 30, 2028
Extract of pyrogenic carbon particles from soils	December 31, 2028
Sample preparation for analytical microscopy and spectroscopy	June 30, 2029
Quantitative high-resolution chemical mapping of metals on biochar particles at different salinities	December 31, 2029
Quantitative high-resolution chemical mapping of organic contaminants on biochar particles at different salinities	December 31, 2029
Publication/dissemination	June 30, 2030

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Dr. Cara Santelli, Assoc. Prof.	University of Minnesota, Department of Earth and Environmental Sciences	Co-Investigator. Dr. Santelli is an expert on environmental detection, fate, and transformation of heavy metals in soils and waters. With her work she seeks a better understanding of the mechanisms of environmental mineral and metal transformation. She will lead the metal quantification experiments and the characterization of pyrogenic carbon surfaces	Yes

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.
For each of the activities, results will be disseminated by peer reviewed publications in archival journals. Data will also be archived in the open access data repository for the University of Minnesota. In both cases, this will make information from the project widely accessible to Minnesotans and other interested parties that are working on biochar and stormwater infrastructure. Results from the project will also be presented at local/regional conferences. We will also communicate key findings to scientists in the Minnesota Pollution Control Agency directly. The Environment and Natural Resources Trust Fund will be acknowledged through use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and presentations.

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 work be funded?
The results will be disseminated to laboratories, agencies, stakeholders and practitioners through open access publications, direct meetings, and conference presentations. If additional work is needed, funding from federal sources will be sought.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Monitoring Emerging Viruses in Minnesota's Urban Water Cycles	M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 04c	$416,000
Impact of Microplastics on Wastewater Treatment in Minnesota	M.L. 2025, First Special Session, Chp. 1, Art. 2, Sec. 2, Subd. 04u	$506,000

Project Manager and Organization Qualifications

Project Manager Name: Sebastian Behrens

Job Title: Assoc. Prof.

Provide description of the project manager's qualifications to manage the proposed project.
Dr. Sebastian Behrens (PI), Associate Professor, is an environmental microbiologist and an expert in detection, identification, and quantification of diverse microbial target sequences in environmental samples based on massively parallel sequencing technologies, quantitative PCR, and flow cytometry. Dr. Behrens follows an interdisciplinary approach that combines the disciplines environmental engineering, and molecular biology to understand the basic

ecological principles driving the biological water treatment processes, the biodegradation of organic contaminants, and the transport and fate of pathogens in the environment. Dr. Behrens has over 10 years of experience working with pyrogenic carbon materials (e.g. biochars) as soil and stormwater filter amendments for water treatment and soil quality management. Dr. Behrens co-founder of the Minnesota Biochar Initiative (MNBI) and serves as scientific advisor on the board of MNBI.

Organization: U of MN - College of Science and Engineering

Organization Description:
The University of Minnesota is one of the largest, most comprehensive, and most prestigious public universities in the United States (http://twin-cities.umn.edu/about-us). The College of Science and Engineering is one of the premier public institutes in the country for graduate and undergraduate education and research. The laboratories and offices of the PIs contain the necessary fixed and moveable equipment and facilities needed for the proposed studies.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Dr. Sebastian Behrens		Principle Investigator: Project coordination, postdoc and grad student advising, analysis of biological processes, publication, and outreach			36.6%	0.36		$90,600
Dr. Cara Santelli		Co-Principle Investigator: Co-advise postdoc and grad students, metal analysis and biochar surface characterization, publication, and outreach			36.6%	0.24		$70,904
Postdoctoral Associate		Data integration, analysis, and publication			26.1%	1		$80,829
Graduate student		Column studies, water quality analysis, soil and biochar characterization			24.2%	0.99		$183,515
Undergraduate student		Support sampling, routine chemical analysis, and maintenance			0%	0.54		$17,192
							Sub Total	**$443,040**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Tools and Supplies	Lab supplies	Chemicals, reagents for water analysis, column experiments, DNA extraction and amplification, consumables					$60,000
	Tools and Supplies	Lab Services	DNA sequencing, ICP-OES (metal analysis), HPLC, analytical microscopy and spectroscopy					$26,000
	Tools and Supplies	Repairs/Maintenance	General lab equipment, centrifuges, PCR, columns, pumps, HPLC, IC, etc.					$10,870
							Sub Total	**$96,870**
Capital Equipment								
							Sub Total	**-**

Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Field sampling, state conferences, presentations; 2-3 sampling trips in year 1+2, 400 miles per year, 2 people	soil + water sampling, miles, meals lodging, conference registration					$2,090
							Sub Total	**$2,090**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Publication costs	Open access publication fees					$8,000
							Sub Total	**$8,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$550,000**

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				
			State Sub Total	**-**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**-**

Total Project Cost: $550,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: b979d174-308.pdf

Alternate Text for Visual Component

Engineered soils (or engineered soil media) are designed to improve stormwater quality, manage runoff, and enhance the resilience of green infrastructure against pollutants and high salinity from road salt. These specialized media are particularly important for the protection and resiliency of soil and aquatic ecosystems receiving stormwater runoff....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
Board of Regents endorsement letter	c80fce2f-9a2.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

Yes, I understand the UMN Policy on travel applies.

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

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

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?

No

Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:

Dr. Cara Santelli, Department of Earth and Environmental Science, University of Minnesota

Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR's reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements

N/A