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

Project Title: **ENRTF ID: 062-B**

Phytoremediation for Extracting Deicing Salt from Roadside Soils

Category: B. Water Resources

Sub-Category:

Total Project Budget: $ 360,231

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

Summary:

We propose to study native plants that can adsorb salts to be planted on the roadside to address the environmental concerns over deicing road salts.

Name: Bo Hu

Sponsoring Organization: U of MN

Title: Associate Professor

Department: Bioproducts and Biosystems Engineering

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Web Address

Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

This visual has some photos about salt damage to the roadside, plants we grow in the lab that we want to use in the research, and an illustration of what we propose to do

_____ 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 STATEMENT:

The icy conditions of Minnesotan winters require aggressive applications of road salts to melt the snow and ice on sidewalks and roads. It is estimated that 365,000 tons of salt is sprinkled in the Twin Cities Metro Area each year [1]. The continued contamination of salt can negatively affect the health of surrounding ecosystem. It is easy to leach into lakes, rivers, and groundwater, causing significantly increased salinity [2]. Many lakes (for instance, Loring pond and Diamond lake) around Metro have already been reported the chloride concentrations consistently surpassing the environmental standard[3] of 230 mg/L. High salt conditions can also negatively affect both plant growth and soil structure. Contaminated soil can affect up to 10 m off of a road side increasing soil density and alkalinity causing problems with erosion and vegetation [1]. Similar to road salt, improper irrigation can also cause salt contamination. Irrigation waters tend to have high concentrations of calcium, magnesium, and sodium ions. Use of this brackish water, particularly without adequate drainage management, results in the accumulation of salts in the rooting zone of plants due to evapotranspiration. This typically results in substantial global agricultural and economic losses, sustenance issues for subsistence farmers, and ecosystem imbalances [4-5]. Planting salt tolerant species can be one way to address this issue. For instance, Dr. Eric Watkins at the University of Minnesota is currently developing salt tolerant turf grasses so that they can grow better for roadsides [6]. Another approach is to develop technologies to remove salt from the soil. This approach will not only address the challenge for the sustainable urban restoration of roadsides and waterways but also provide an opportunity to regain agricultural croplands, revitalize rural economy and increase global food security [2].

Phytoremediation is an emerging method to extract salts from the soil by utilizing the growth of certain plants and remove salts by harvesting the plant biomass. These plants are typical halophytes, which excrete salt ions through specialized leaf glands[7]. Phytoremediation has numerous advantages over the conventional techniques for salt remediation, such as removing the contaminated soil to landfill while replacing it with clean soil, leaching, chemical amendments, and organic amendments. Phytoremediation is environmental friendly than the landfill of affected soil since this soil will have the opportunity to be re-used. It can also be more easily applied and less costly than the leaching and amendment methods. The harvested halophytic plant biomass may have some industrial applications, for instance, serving as animal feed or energy source.

Glasswort *Salicornia rubra (S. rubra)* is a succulent halophyte which is found growing in Kittson County, Minnesota. It grows on the saline areas such as salt flats, alkaline depressions, exposed shores of alkaline lakes, and saline swales [8]. Despite not being commonly found in central Minnesota, recently *S. rubra* has been observed growing next to major highways in the Twin Cities [8]. It is predicted that this is a result of the increased salinity of roadside soil, which is the ideal growing condition of *S. rubra* in its natural habitat. Since it is a native grass, *S. rubra* is suitable to MN climate and does not pose any economic threat to the local ecosystem. We believe that *S. rubra* has a great potential to be used for phytoremediation to remove and stabilize salts from the soil surrounding MN roads and lakes. *S. rubra* can uptake salts from the soil, bringing it into the above-ground plant tissues, and then reduce salt contamination through grass mowing and collection. This project will study the potential of *S. rubra* and other native species for the phytoremediation to remove salts from roadside soil and farmland [1].

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Screening of native Minnesota halophytic plants **Budget: $116,005**

We first want to study the halophytic plant inventory and screen more native species *via* lab growth tests for phytoremediation purpose. Around 200 distinct halophytic species are reported in the U.S., growing in coastal and inland regions [9]. Several studies have been done on these plant species, covering wide ranges of topics including halophyte ecology and physiology, and their utilization in farming systems. MNDNR publishes on their website about all the plant species living in the state of MN and we will compare with the reference to identify more halophytic species [8] suitable for MN conditions. We will grow some plants in the lab to screen more species that are native in MN and suitable to grow on the roadside. *S. rubra* and other potential specimen will be planted under varying salt concentrations to study optimal growing conditions. The plants will be kept in the same room

with lights placed over the pots to simulate day and night. Plant height and leaf chlorophyll will be measured every 10 days. Salt content of the biomass will be measured after two month of growth at each conditions to determine the best candidate for road salt removal from soil.

Outcome	Completion Date
1. Select halophyte plants with the ability to grow in MN	Year 1 - 01/2020
2. Screen halophyte plants with lab growth for salt removal capability	Year 1 - 05/2020

Activity 2: Plant growth test on salt-affected soil **Budget: $120,023**

We will consult with MNDOT to identify a slot of area for some pilot plant growing tests. The selected specimen from the lab tests will be planted in the spring on this pilot testing lot and monitored for the entire growing season. Based on the literature, it will take *S. rubra* 2-3 weeks before they grow to the market height and it is expected the plants can keep removing salts when the grass is mowed and collected. We will measure the plant biomass, nitrogen (TN), phosphorus (TP and PO_4-P), and the salt concentration in the shoots, roots, and soil. We will use this information to develop an implementation plan for how this species will be added into current regional seed mixtures for plantation diversity and how to maintain their growth. The plan will also consider effects of this species on the roadside stabilization and safety, a better outcome for NPDES permit compliance for obtaining a uniform, perennial cover, changes to standard specification for construction activities, structural root system enhancement that increase the shear resistance for reducing soil slides, flood overtopping stability, etc.

Outcome	Completion Date
1. Pilot plant growth in a field	*Year 2 – 12/2020*
2. Evaluation and analysis of samples for pilot growth study	*Year 2 – 05/2021*

Activity 3: Develop possible utilization of harvested plant biomass **Budget: $124,203**

It is important to find a utilization of the biomass in order to cover the cost of harvest, and provide an economically sustainable solution. We will study the utilization of the biomass for animal feed supplement, energy source, and for recycled road salts after ashing. *S. rubra* has been reported as the ingredient supplement to improve the flavor and nutrition of the animal feed. The plant biomass will be analyzed for its feed value, including the following parameters: gross energy, fiber, total protein and amino acid profile, phosphate, lipids, and possible accumulation of heavy metals. The plant biomass can also be combusted for heat and power, meanwhile the ash can be recycled as the road salts.

Outcome	Completion Date
1. Biomass characterization for possible applications	*Year 3 - 10/2022*
2. Business strategies for how to adopt this plant for road side applications	*Year 3 - 06/2022*

III. PROJECT STRATEGY

A. Project Team/Partners: The team includes Professor Bo Hu and his postdoc researcher from the Department of Bioproducts and Biosystems Engineering Department, University of Minnesota. We are partnering with the MN Department of Transportation for our field study and the supporting letter is attached to the proposal.

B. Project Impact and Long-Term Strategy: The project will have a broad impact on both academia and industry. The results will provide fundamental knowledge on how these native plants mobilize and excrete salt in the soil. The possible applications will lead to sustainable developments in road salt management and agricultural practices, and alleviate the deteriorating conditions related to road salt application and improper irrigation.

C. Timeline Requirements: The project will be completed in 3 years, with the first year for growing testing and lab-scale study and the following years for on-site field trials to evaluate success in the field and further develop implementation technologies.

2019 Detailed Project Budget

Project Title: Phytoremediation for Extracting Deicing Salt from Roadside Soils

IV. TOTAL ENRTF REQUEST BUDGET 3 years

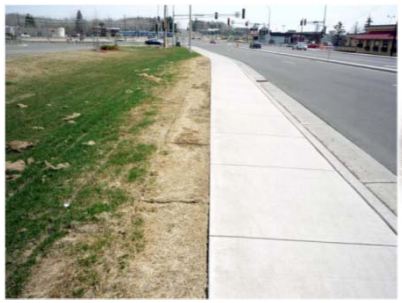
BUDGET ITEM	AMOUNT
Personnel:	
Bo Hu, Project Manager (74.5% Salary, 25.5% Benefits), 10% FTE per year for three years	$ 45,603
Research Associate (74.5% Salary, 25.5% Benefits), 50% FTE for 3 years	$ 104,730
Graduate student, Research assistant, 50% FTE	$ 145,906
Undergraduate student researcher, 800 hours	$ 15,608
Professional/Technical/Service Contracts	
Professional analysis service for water and solid samples at other UMN analytical labs	$ 9,365
Equipment/Tools/Supplies:	
Supplies for the lab experiments to purchase necessary chemicals, test kits, culture medium, and other materials	$ 31,215
Acquisition (Fee Title or Permanent Easements): N/A	$ -
Travel:	$ -
In-state travel (Mileage, lodging, and meals) to the site for collecting water samples	$ 4,682
Additional Budget Items	$ -
Publication costs for two/three papers, page charges	$ 3,122
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 360,231

V. OTHER FUNDS

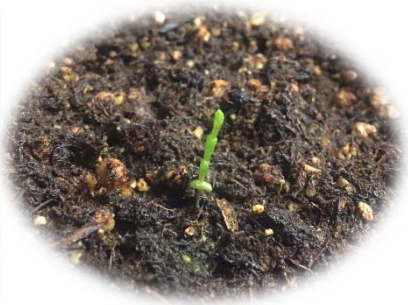
SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:	$ -	
Other State $ To Be Applied To Project During Project Period:	$ -	
In-kind Services To Be Applied To Project During Project Period	$ 169,380	*UM F&A*
Past and Current ENRTF Appropriation:		
Other Funding History:	$ -	

Phytoremediation for Extracting Deicing Salt from Roadside Soils

Bo Hu, Bioproducts and Biosystems Engineering, University of Minnesota



Effects of de-icing agent on the vegetation of the road shoulder (photo courtesy from Stenlund, Dwayne



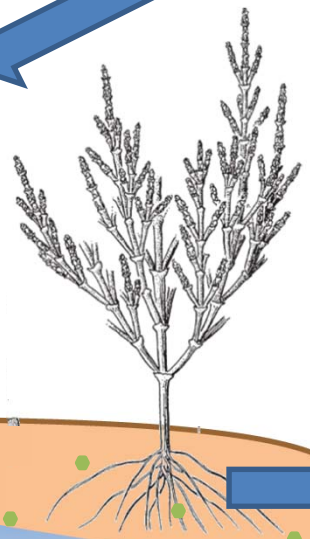
Glasswort *Salicornia Rubra* is a native plant growing in a few salty lakes in Western Minnesota

Harvest

Recycle for road salts
Animal feed
Energy source

Road salts

Transfer salt above ground to plant tissues



Increase soil salinity

Leaching to the rivers, lakes, and groundwater

Salt uptake by roots

Bioswales / Roadside design

Activity 1: Screening of native Minnesota halophytic plants

Activity 2: Plant growth test on salt-affected soil

Activity 3: Develop possible utilization of harvested plant biomass

Project Manager Qualifications

The research team will include Dr. Bo Hu and his Post-Doc researcher and PhD graduate student from the Department of Bioproducts and Biosystems Engineering.

Dr. Bo Hu is a junior Associate Professor at Department of Bioproducts and Biosystems Engineering, University of Minnesota. With more than 18 years of active research experience specifically in bioprocessing development, nutrient removal, and waste management, he is leading projects to remove phosphorus from manure and from wastewater in the septic tank systems, projects to reveal the myth of recent swine manure foaming in Midwestern states, projects on synthetic ecology in lichen biofilm formation by co-culturing mixotrophic microalgae and filamentous fungi. He has finished projects to develop a community microbial electrochemical septic system and a fungal biofilm system for water treatment. Dr. Hu's team at UMN has set up several standard procedures such as 16s rDNA based microbial analysis by using high-throughout pyrosequencing methods to study the microbial species in the waste treatment processes, ITS sequences to identify fungal species. His team is also developing several conversion platforms, such as lichen biofilm co-cultivation of fungi and microalgae, pelletized fungal fermentation, and solid and hemi-SolidSF of filamentous fungi, to produce bioprducts and biofuel from agricultural waste and residue, and to remove nutrients and pollutant from contaminated water. As the PI of the project, Dr. Hu will design and coordinate the research; the Post-Doc researcher will assist in design and experimentation; and the graduate student will assist in data collection and dissertation.

Dr. Hu's laboratory has all the necessary equipment and facilities for this project, including: Bio-Rod MJ Mini 48-Well Personal Thermal Cycler, Bio-Rod electrophoresis, New Brunswick refrigerated incubation shaker INNOVA 42R, New Brunswick shaker Excella E-24, Beckman Allegra X-15R Refrigerated Centrifuge, VWR refrigerated water heater circulator, Bioreactor/fermentor, Agilent 7820 A GC-FID-TCD [gas-chromatography analysis–flame-ionization detector–thermal conductivity detector] , Agilent Micro-GC, Agilent 1260 HPLC (Diode Array detector, Refractive Index Detector and autosampler), and Dionex ICS 2100/ ICS 1100 bundle ThermoFisher Scientific. Other basic equipment within the lab includes Biosafety cabinet, Autoclave, -20 freezer and 4 degree refrigerator, balances, pH meter, etc.. The lab is also equipped with two incubation rooms with full range of temperature control, a walk-in refrigeration room and a walk-in cold room.

As a participating faculty of Biotechnology Institute of UMN, Dr. Hu has the access to the Biotechnology Resource Center, which is a 4000 square-foot laboratory/pilot plant facility with state-of-the-art equipment for research and development in fermentation, animal cell culture technology, molecular biology, protein expression, and separation of a wide range of biological molecules. The facility has a wide range of bench-scale to pilot-scale fermenters available, ranging in size from 6 L to 300 L. The university also has the following facilities that can be accessed with payment: Center for Mass Spectrometry and Proteomics. This facility is house in the basement of the Gortner / Snyder complex and provides support, equipment and expertise for analyzing complex protein mixtures. This facility has several full-time staff trained to run and troubleshoot experiments. It is an NSF funded core facility (NSF Grant 9871237, Dr. Gary Nelsestuen, PI) and is home to the University of Minnesota Mass Spectrometry and Proteomics Initiative that can provide matching funds for in house proteomic projects.

Organization Description

As the core department of UMN to tackle Agricultural engineering and environmental engineering issues, Bioproducts and Biosystems Engineering Department has very dynamic research activities and numerous excellent scientific researchers have received grant supports from LCCMR program. UMN Sponsored Projects Administration (SPA) will be the entity authorized by the Board of Regents to manage the project agreements with LCCMR program.