[M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04o as extended by M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 18] Project Abstract
For the Period Ending June 30, 2022

PROJECT TITLE: Evaluating Locally-Sourced Sanding Materials for Road Salt Reduction
PROJECT MANAGER: Chan Lan Chun
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04o as extended by M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 18

APPROPRIATION AMOUNT: $ 162,000.00
AMOUNT SPENT: $ 161,999.45
AMOUNT REMAINING: $0.55

Sound bite of Project Outcomes and Results

This project evaluated local ecological abrasive materials for use as alternative materials to lower road salt use in winter maintenance and consequent environmental impacts. The findings are useful for the development of the formulation and application practice for both water resource protection and safe winter roadway.

Overall Project Outcome and Results

The use of chloride-based salt as a deicer for winter road maintenance has been a longstanding practice throughout the state of Minnesota and the country. However, once chloride enters the water, it is not naturally broken down, transformed, or removed from the environment, resulting in accumulation in the watershed and detrimental ecological and water quality impacts in freshwater systems. To protect freshwater resources and to prevent this issue from worsening with time, an alternative method for providing sustainable and effective winter road maintenance is needed. In some cold regions of Minnesota, sand is mixed with salt as an abrasive to provide additional traction to the roads; however, its effectiveness is not well established. This project investigated the potential of regionally available organic and inorganic industrial byproducts as alternatives to conventional sand and salts. Candidate materials include corn grit, timber waste, and taconite waste rocks local to Minnesota. Chemical and physical properties of the materials were characterized, including material elemental composition, morphology, particle size distribution, and specific gravity to establish a foundational understanding of the material. Skid resistance and deicing tests with environmental impact assessment were performed to evaluate traction effectiveness and material safety. The results showed potential for bio-based materials such as corn grit and bark mulch as a sorbent for salt brine deicer with less salt impact and for the waste iron-bearing minerals to be used as effective abrasives in the realm of winter road maintenance. The use of alternative materials for winter road maintenance show promise for lower environmental impact, lower/controlled chloride pollution, increased friction enhancement, and beneficial reuse of industry waste material. In addition, this work provided a streamlined method for evaluating potential abrasives/deicers which will be valuable for expediting future studies of alternative materials.

Project Results Use and Dissemination

The project findings have been disseminated via reports to LCCMR, master student's thesis, and presentations at regional conferences (Minnesota Water Resources Conference and UMD seminar series). The project findings were shared with the public through public outreach activities for 6th-12th graders and general audience: engineering discussion with middle school students of Arcadia Charter School, Northfield, MN and a video clip, Safe Roads and Healthy Water to present and discuss our project for achieving safe roads and healthy water using local materials for the UMD's STEM Discovery Day.

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2019 ENRTF Final Work Plan

Today's Date: August 12, 2022

Final Report

Date of Work Plan Approval: June 5, 2019

Project Completion Date: June 30, 2022

PROJECT TITLE: Evaluating Locally-Sourced Sanding Materials for Road Salt Reduction

Project Manager: Chan Lan Chun

Organization: University of Minnesota Duluth

College/Department/Division: Civil Engineering and Natural Resources Research Institute

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Location: Statewide

Total Project Budget: $162,000
Amount Spent: $161,999.45
Balance: $0.55

Legal Citation: M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04o as extended by M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 18

Appropriation Language: $162,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota for the Natural Resources Research Institute in Duluth to evaluate the effectiveness and benefits of using locally sourced wood chips, corncobs, and iron-bearing minerals as alternative abrasive materials to lower salt use for protecting Minnesota's water resources. This appropriation is subject to Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2021, by which time the project must be completed and final products delivered.

M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 18. ENVIRONMENT AND NATURAL RESOURCES TRUST FUND; EXTENSIONS. [to June 30, 2022]

I. PROJECT STATEMENT:

Minnesota uses hundreds of thousands of tons of salt annually for winter road maintenance. Unfortunately, road salt is also a major contributor to elevated chloride levels in Minnesota water bodies because the chloride in road salt is not naturally broken down, transformed, or removed from the environment. Elevated chloride levels have detrimental impacts on ecological and water quality, including toxicity to aquatic life in freshwater and contamination of drinking water supplies. Along with road salt, sand is the most common abrasive used at all temperatures, particularly during very cold temperatures when salts are ineffective. But the use of conventional sands has been declining to straight road salt application due to a recognition of their limited effectiveness in sand/salt mixtures. So how might chloride loadings be reduced? By using locally sourced alternative sanding (abrasive) materials. There are natural materials such as woodchips, corncob, and iron-bearing minerals which may be better alternatives to sand. Their effectiveness and environmental benefits/impacts, however, have not been examined in Minnesota.

The proposed project will evaluate the effectiveness and feasibility of locally available natural materials including agricultural and iron industry byproducts as alternative effective abrasive materials to sand. The materials include corncob, various types of woodchips, and iron industry byproducts such as taconite tailings, crushed iron ores, and processing byproducts. Potentially, these materials may not only offer traction and skid resistance required on the icy and frozen roads during winter, but also hold effectiveness of salt for a longer duration and capture other contaminants on roads. We hypothesize that more effective sanding materials on roadways will eventually lower salt use for the protection of water resources. In addition, agricultural byproducts are biodegradable, and iron industry byproducts have high solar absorbance to enhance deicing efficiency. This project will characterize their physical and chemical properties, develop the formulation and application practice to use them as sanding materials with the combination of chloride and non-chloride deicers, and assess their deicing efficacy and potential environmental impacts and benefits. The results of this project will lead environmental benefits: reducing impacts of chloride on watersheds through the reduction of road salt use, and beneficially utilizing waste and byproduct materials as green and more-effective sanding alternatives. The project outcome will provide essential information for the development of implementation research.

II. OVERALL PROJECT STATUS UPDATES

First Update March 1, 2020

Starting on July 1, 2019 most work was performed with Activity 1. The database of potential locally-available materials for winter road maintenance has been created in consultation with research partners and local industries. Initially, 12 materials were obtained and 5-7 more materials are in the process of acquirement. The characterization of their physical and chemical properties for abrasive materials are in progress. Activity 2 has not started yet because it is based on the results of Activity 1. We started to develop the analysis scheme and flowchart to evaluate for traction and deicing efficiency and potential environmental impacts for Activity 2.

Second Update October 25, 2020

Since the last report, we have made progress on procurement of additional locally sourced materials and physical material characterization in Activity 1. Based on initial characterization of their physical and chemical properties, the analysis scheme was developed for Activity 2. Traction and deicing efficiency experiments have been designed with instrument calibration. Leaching experiments are in progress for potential environmental impact study this Fall. However, the laboratory testing and analysis were on hold during March-June 2020 due to the COVID-19 pandemic (e.g. the University's lab hibernation and the State's "Stay Home" order). Laboratory analysis has been resumed this summer. As consequence, we requested a no-cost extension to complete the original scope of work.

Third Update March 25, 2021

Since the last update, we completed materials characterization for Activity 1 and have compiled the results together. Based on the analysis scheme developed for Activity 2, we made progress on traction and deicing efficiency experiments and material leaching experiments for the candidate materials with MNDOT reference materials. The traction and deicing experiments were conducted in both laboratory and field sites. Based on initial analysis, good and weak properties of each material for deicing and skid resistance have been evaluated, and they are used to develop formulation (e.g. mixture of organic and inorganic materials) as alternative materials for winter road maintenance with less environmental impact.

Project extended to June 30, 2022 by LCCMR 6/30/21 as a result of M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 18, legislative extension criteria being met.

Fourth Update October 25, 2021:
Activity 1 tasks excluding hardness and bulk density have been completed. For Activity 2, deicing and traction performance of raw materials have been completed. Currently we are formulating the materials such as brine-soaked materials which can be used as both deicer and abrasive and their performance of deicing and traction are in progress. Environmental leachate and contaminant sorption capacity experiments have been conducted to assess potential environmental impacts of these ecological materials. Final formulation of material composite will be completed this winter and the mixtures will undergo a final skid resistance and deicing capacity performance evaluation to inform the final recommendation.

Fifth Update March 25, 2022:
Since the last update, we have finished tasks outlined in Activity 1 and 2 and have been working on data analysis, drafting, and identifying gaps in the current status of the research collected that may be necessary/feasible to address prior to completion of the project. Current results show promise for the use of brine infused corn grit as a potential deicer alternative but there are environmental concerns for its use such as organic and nutrient impacts as well as durability on the roadway. To address these concerns, application scale and cleanup protocol will be important factors in determining impact, i.e. use on low vehicular speed roadways paired with road sweeping cleanup are predicted to have the best performance while minimizing environmental impact. Both waste rocks (OX and MES) show promise for use as a friction additive with results showing higher friction enhancement to both asphalt and concrete road surfaces than conventional sand abrasive. Due to turbidity concerns from the environmental leaching study of OX waste rock, MES waste rock is currently the preferred choice for a friction enhancer during winter maintenance.

AMENDENT REQUEST April 26, 2022
We are requesting funds be shifted from the supplies budget line to personnel.

Printing budget would be decreased by $263 to a revised budget of $13
Travel budget would be decreased by $1,067 to a revised budget of $133
Lab service would be decreased by $ 2,670 to a revised budget of $4,330
Personnel budget would increase by $1,500 to a revised budget of $132,024
Supplies budget would be increased by $2,500 to a revised budget of $25,500

These changes are being requested because more staff time and lab supplies are needed to accomplish Activity 2, Outcome # 2 &3. To pay for these costs, we will use savings accomplished in Printing and Travel budget for dissemination activities and Lab Service budget for Outcome #2 in Activity 1. All dissemination activities have been conducted virtually due to the pandemic. The cost of SEM analysis in Lab service budget can be decreased for Outcome #2 in Activity 1 as we have completed the SEM analysis for most of samples more efficiently.

Amendment approved by LCCMR 5/4/2022

Overall Project Outcomes and Results
The overall goal of the research was to evaluate the potential of different locally sourced byproduct material for use as alternative materials to lower road salt use in winter maintenance and consequent environmental impacts. The goal was structured through primary objectives of (1) evaluating performance potential, (2)

considering environmental impacts, and (3) suggesting final recommendations with initial results and brine infused materials. The study was conducted through physical and chemical property characterization, de-icing experiments, traction experiments, leachate study, sorption study, a brine-infusion and recommendations. Evaluation was considered at each stage with a final recommendation as stated below.

The materials best fit in terms of winter maintenance abrasive application were found to be the inorganic waste rocks due to their preferred higher angularity, size range, and measured friction performance. An additional benefit of the waste rocks that was not directly measured in this study but could be higher solar sorption due to darker material color. This may enhance deicing. The hardness of rock material is also likely to have better longevity and durability on the roadway. Primary environmental concerns with waste rock use were found to be with turbidity that could have negative environmental consequences concerning PM10 contribution and watershed pollution/geology. The materials best fit in terms of winter maintenance deicer application were found to be the corn grits due to their higher brine retention and contaminant sorption capacity. The mulches performed secondary for friction and deicer performance but were comparable to the higher performing materials and therefore may have potential for use in both winter maintenance applications. Primary environmental concerns with organic materials were found to be potentials for nutrient and TOC loadings. This may cause negative environmental consequences for sensitive watersheds and should be appropriately considered.

The findings for this study will help to guide potential fit for the materials' application within the realm of winter road maintenance and water resource protection. In addition, the project approach and methods may be used as a reference and/or starting point for similar projects seeking to evaluate material fit. The use of alternative materials for winter road maintenance show promise for lower environmental impact, lower/controlled chloride pollution, increased friction enhancement, and beneficial reuse of industry waste material.

<u>Overall Project Outcome and Results</u>

The use of chloride-based salt as a deicer for winter road maintenance has been a longstanding practice throughout the state of Minnesota and the country. However, once chloride enters the water, it is not naturally broken down, transformed, or removed from the environment, resulting in accumulation in the watershed and detrimental ecological and water quality impacts in freshwater systems. To protect freshwater resources and to prevent this issue from worsening with time, an alternative method for providing sustainable and effective winter road maintenance is needed. In some cold regions of Minnesota, sand is mixed with salt as an abrasive to provide additional traction to the roads, however its effectiveness is not well established. This project investigated the potential of regionally available organic and inorganic industrial byproducts as alternatives to conventional sand and salts. Candidate materials include corn grit, timber waste, and taconite waste rocks local to Minnesota. Chemical and physical properties of the materials were characterized, including material elemental composition, morphology, particle size distribution, and specific gravity to establish a foundational understanding of the material. Skid resistance and deicing tests with environmental impact assessment were performed to evaluate traction effectiveness and material safety. The results showed potential for bio-based materials such as corn grit and bark mulch as a sorbent for salt brine deicer with less salt impact and for the waste iron-bearing minerals to be used as effective abrasives in the realm of winter road maintenance. The use of alternative materials for winter road maintenance show promise for lower environmental impact, lower/controlled chloride pollution, increased friction enhancement, and beneficial reuse of industry waste material. In addition, this work provided a streamlined method for evaluating potential abrasives/deicers which will be valuable for expediting future studies of alternative materials.

III. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1 Title: ***Physical and chemical properties of bio-based materials and iron-bearing minerals as alternatives to sand***

Description: We will explore and review locally available natural resources as alternative sanding materials for winter road maintenance. Locally sourced materials include bio-based materials such as corncob-derived abrasive and wood or bark mulches, and iron industry byproducts including taconite tailings and processing byproducts. As for corncob materials, we will test both a commercial abrasive derived from corncob (e.g., Abrasives INC) and raw corncob materials for processing. The raw corncob materials will be obtained through communication with the Minnesota Corn Growers Association and University of Minnesota Extension. Woodchips and bark mulches will be collected from forestry product industries (e.g., pulp and paper mills and biofuel industry) across Minnesota. Locally sourced iron-bearing materials will be explored from the iron industry across the Mesabi Range in northeastern Minnesota. Taconite tailings that are currently utilized as road aggregates by the Minnesota Department of Transportation (MnDOT) will be included. The candidate locally-sourced materials will be paired with commercial products of alternative ecological abrasives for winter road maintenance if available. For examples, the candidate wood chips and bark mulches collected from forestry product industries (e.g., pulp and paper mills, sawmill and wood product plants) across Minnesota will be evaluated with commercial woodchip-based abrasive such as Stop Gliss Bio® and Eco Ice Grip. These materials will be screened based on MnDOT's current specification and recommendations of materials for winter road abrasive applications, which are larger than 297 micron (ASTM Sieve No. 50) and smaller than 3/8 inch. Moreover, the sand materials currently used by MnDOT for winter road maintenance will be tested as reference materials. When the materials are collected, the characterization data that are available from literature and previous studies will be collected and compared for the selection of candidate materials to be tested.

Physical and chemical properties of the candidate materials will be characterized. The characterizations include particle size distribution, physical properties, and chemical compositions. Particle size distribution will be measured by sieving method according to American Society of Testing and Materials C33 (ASTM, 2016). The mechanical properties including hardness, angularity, density, and silt content will be examined to determine if the candidate materials meet required qualities of sanding/abrasive material for winter maintenance. Chemical compositions of the materials will be determined by wet-chemistry extraction methods including water extraction, week acid extraction, and aqua regia digestion. As for iron-bearing mineral materials, mineralogical composition will be examined using x-ray diffraction. Morphological features and surface chemical composition will be observed using scanning Electron Microscopy equipped with an energy dispersive x-ray spectroscopy (element mapping).

ACTIVITY 1 ENRTF BUDGET: $ 71,~~200~~000

Outcome	Completion Date
1. Database of locally available natural byproducts for the selection of abrasive materials	October 31,2019
2. Selected abrasive materials characterized: Chemical and mineralogical composition and physical properties	June 30, 2020

First Update March 1, 2020

We have created the database of locally available materials bio-based materials and iron industry byproducts along with commercial products MNDOT and MN cities are using for winter road maintenance. Among them, we have obtained 5 iron industry byproducts (overburden natural rocks and taconite tailing), 4 bio-based materials (corncob-derived abrasives, wood and bark wastes), and 3 commercial abrasives. MNDOT District 1 provided sands, salts, and brines they currently applies for the road. Particle size and distribution analysis of raw materials were completed, and the materials were reformulated comparable to MNDOT sand materials as the reference material. Mineralogy analysis is completed using x-day diffraction for iron-bearing materials. Characterization of physical and chemical properties of the candidate materials is in progress. The mineralogical composition was identified by XRD. They are composed of quartz (SiO_2), silicates (e.g. lizardite and chlorite), Fe^{II} mineral (iron silicate; siderite, iron carbonate; dolomite, calcite and aragonite, iron-titanium oxide; ilmenite), and Fe^{III} minerals (hematite, goethite, lepidocrocite). Quartz, common mineral in sand, accounts for 75-98 % of materials. The mechanical properties including material loss by abrasion, angularity, density, and silt content are currently examined to evaluate if they are suitable as abrasive materials for winter road maintenance. In addition to the materials obtained for the characterization, we are in communication with local industries and public agencies to acquire 5-7 more materials for the project.

Second Update October 25, 2020

We procured additional 5 mineral materials which are currently used as aggregates for pavement and pothole patches and have characterized their physical and chemical properties. Based on initial characterization of 17 materials, we decided to use candidate materials with the particle size of between 0.15 and 4.75 mm for downstream analyses in Activity 1 and 2. A subset of exemplary samples are shown in Figure 1 with MNDOT sand as a reference materials. As MNDOT used washed sand which has low silt content (slip contribution), the particle size range eliminated silt portion. We have reconstituted the candidate materials to this particle size range. Currently the measurement of their bulk density and angularity is in progress. In addition to their physical properties, chemical (elemental) composition of materials was examined by aqua regia digestion (Table 1.1). Generally, mineral-based materials contain iron, calcium, and magnesium with less than 0.1% of heavy metals (Zn, Cr, Cu, Co, Ni, Pb). Figure 1.2 shows scanning electron microscopy images of selected mineral samples. We will complete this activity by the end of December.

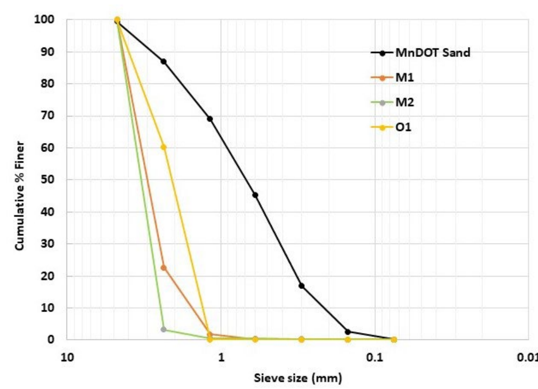


Figure 1.1. Particle size distribution of fomulatated materials for traction, deicing, and enviromental impact research in comparison to MNDOT sand.

Table 1.1. Elemental composition (%) of the selected material quauntified by ICP-OES after Aqua Regia digestion

ID	Al	B	Ca	Fe	K	Mg	Mn	Na	P	S	Si[a]	Ti	Zn
T-MI[b]	0.19	0.04	0.33	26.65	0.56	4.08	0.11	0.11	0.06	0.08	0.12	1.35	0.03
RW-OS	0.33	0.05	0.71	21.42	0.61	1.47	0.16	0.10	0.07	0.12	0.07	0.01	0.04
RW-IO	0.08	0.04	0.74	39.91	0.55	0.09	1.27	0.23	0.31	0.04	0.16	0.00	0.03
TD-IO	0.15	0.03	1.68	10.58	0.55	0.82	0.74	0.18	0.22	0.09	0.07	0.00	0.03

[a]Si was not fully digested; [b]T-MI contained 0.14, 0.18, and 0.04 % of Cr, Cu, and V, respectively; and [*]Elements below detection limit (<0.01 %): As, Ba, Be, Co, Li, Ni, Mo, Pb, Rb, Sr, and V

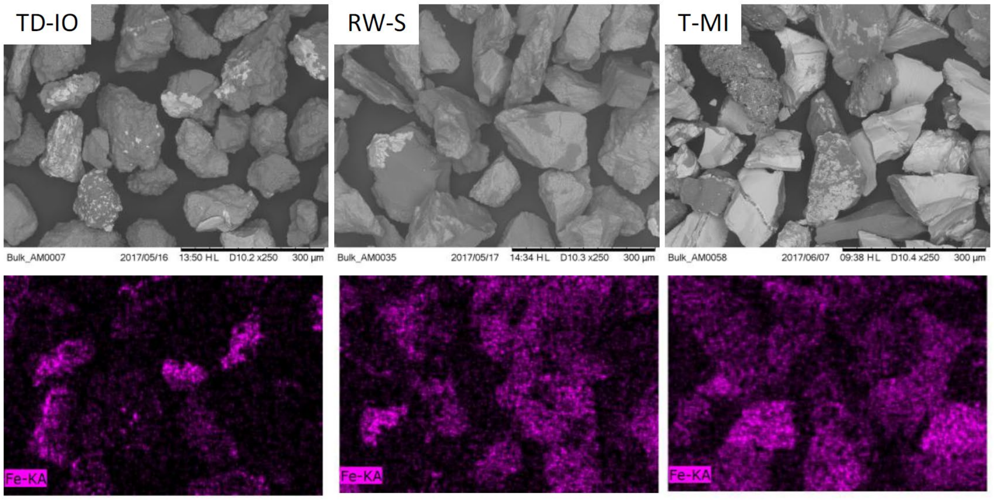


Figure 1.2. Scanning electron microscopy (top) and eletmental (iron) mapping images (bottom) of TD-IO, RW-S, and T-MI as representative mining materials

Third Update March 25, 2021

Aqua Regia digestions for elemental composition analysis of the selected organic and mineral materials were completed. Digestate were submitted to the UMN Research Analytical Laboratory for ICP analysis for determination of final concentration. Morphological analysis of the materials selected for Activity 2 were examined using scanning electron microscope (SEM) analysis. SEM analysis of the candidate materials provide useful observations regarding material porosity, angularity, uniformity, and material surface elemental composition. Figure 1.3 shows morphological difference between the corn grit and MNDOT sand. The candidate organic abrasive materials, corn grits have porous surface structure but lower angularity, suggesting it has potential holding capacity of salts but low friction potential unlike MNDOT reference sand materials. Based on the characterization of the candidate materials, we identified good and weak properties of each materials for deicing and skid resistance for material selection and formulation for Activity 2.

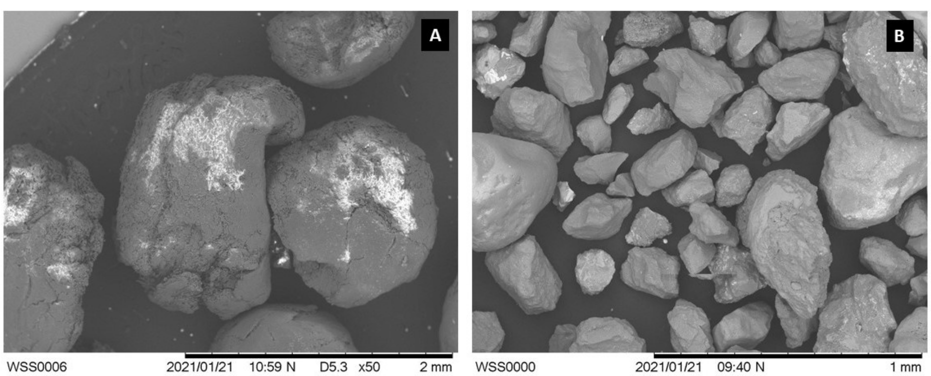


Figure 1.3. Scanning electron microscopy images of the candidate abrasive corn grit and MNDOT reference material sand (reference materials)

Fourth Update October 25, 2021:

Elemental composition of all materials using Aqua Regia digestion is compiled in Table 1.2 and Figure 1.4. The materials are primarily composed of iron, calcium, aluminum, magnesium, and silica with the organic material composition being dominant in calcium and the inorganic material composition being dominant in iron. The materials contain no or very low concentration (< 0.02%) of heavy metals (Pb, Zn, Cu, Cr etc.), indicating these materials are safe to road application.

Table 1.2 Elemental composition of all materials in this study

Sample ID	Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	K	Li	Mg	Mn	Mo	Na	Ni	P	Pb	Rb	S	Si	Sr	Ti	V	Zn
MnDOT sand	2.21	0.00	0.01	0.01	0.00	6.99	0.00	0.01	0.05	0.03	12.07	0.15	0.00	2.11	0.15	0.00	0.40	0.39	0.37	0.00	0.00	0.06	0.61	0.03	0.16	0.01	0.03
Mesabi taconite waste rock (old)	1.54	0.06	0.08	0.00	0.00	4.00	0.00	0.04	0.00	0.00	81.82	0.73	0.00	5.78	1.14	0.00	0.12	0.01	0.11	0.00	0.00	0.23	1.23	0.02	0.02	0.02	0.01
Oxitec taconite waste rock (old)	0.38	0.00	0.04	0.00	0.00	1.12	0.03	0.00	0.00	0.00	73.22	0.00	0.00	0.01	0.46	0.00	0.03	0.00	0.07	0.00	0.00	0.02	0.58	0.00	0.00	0.01	0.00
Mesabi taconite waste rock (new)	1.80	0.00	0.11	0.00	0.00	4.93	0.00	0.00	0.00	0.00	112.00	0.35	0.00	7.62	1.57	0.00	0.12	0.00	0.16	0.00	0.00	0.09	0.30	0.02	0.03	0.02	0.01
Oxitec taconite waste rock (new)	0.31	0.01	0.04	0.01	0.00	3.42	0.00	0.01	0.05	0.00	75.13	0.18	0.00	0.16	3.76	0.00	0.08	0.28	0.04	0.00	0.00	0.04	0.69	0.02	0.01	0.01	0.00
Blended bark mulch	0.29	0.00	0.01	0.06	0.00	13.36	0.00	0.00	0.00	0.02	0.96	0.76	0.00	0.65	0.24	0.00	0.30	0.00	0.27	0.00	0.00	0.16	0.28	0.06	0.01	0.00	0.09
Blended birch mulch	0.58	0.00	0.00	0.02	0.00	10.27	0.00	0.00	0.01	0.01	0.40	0.62	0.00	0.23	0.18	0.00	0.19	0.03	0.12	0.00	0.00	0.09	0.14	0.05	0.00	0.00	0.06
Corn blast media	0.01	0.00	0.00	0.00	0.00	3.50	0.00	0.00	0.00	0.01	0.00	4.12	0.00	0.17	0.00	0.00	0.08	0.00	0.18	0.00	0.00	0.09	0.23	0.02	0.00	0.00	0.00
Zeolite	9.82	0.02	0.00	0.19	0.00	9.23	0.00	0.00	0.01	0.01	2.08	11.96	0.00	0.49	0.22	0.00	11.95	0.04	0.05	0.02	0.02	0.00	0.19	0.09	0.01	0.00	0.00

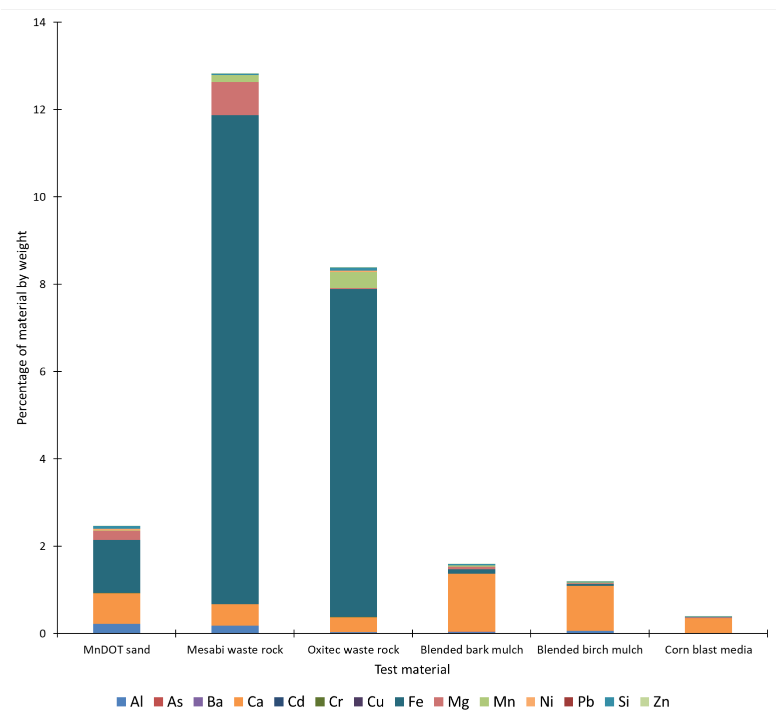


Figure 1.4. Major elements of the materials in this study. The materials were digested using Aqua Regia.

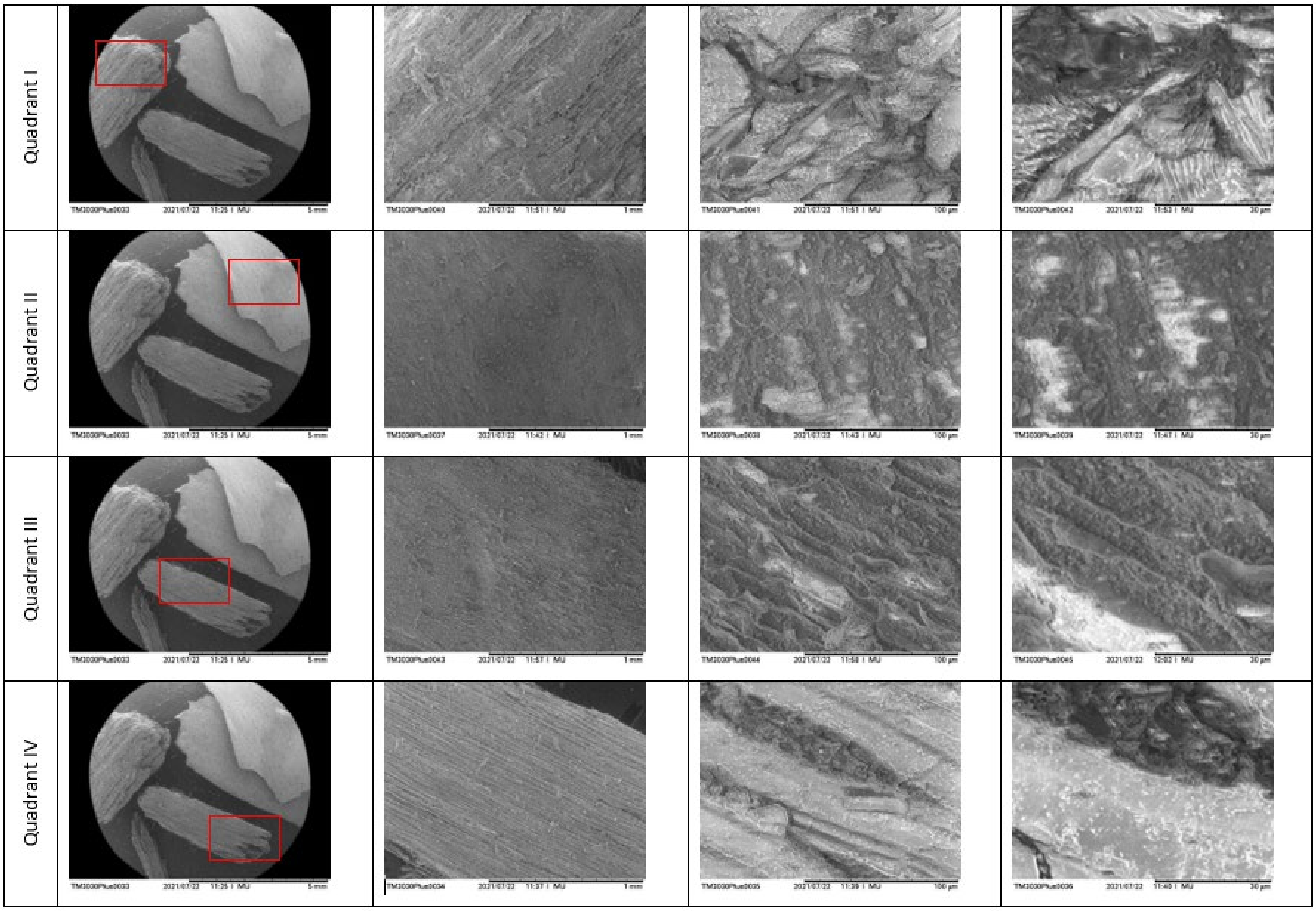
Specific gravity tests were performed to gain information on material density and surface area application rates (versus application rates determined solely by weight) and are shown in Table 1.3. Due to flotation of the organic materials during the test, specific gravity values for materials in the organic class were not able to be accurately determined by specific gravity standard methods and are currently listed as less than 1. Additional methods, such as bulk density, will be chosen and performed on all project materials in order to determine surface area application rates.

Table 1.3 Specific gravity of the materials in the study

Material	Bulk Specific Gravity	Apparent Specific gravity	Water Absorption capacity, %
Oxitate	3.08897	3.30044	2.07429
Mesabi	2.821	3.10791	3.27242
Corn grit	<1	<1	-
Bark mulch	<1	<1	-
Birch mulch	<1	<1	-
MnDOT sand	2.75044	2.82837	1.00172

Complete standardized SEM imaging has been completed for all project materials. Results for the birch mulch material are shown in Table 1.4 All other material imaging has been documented in the same format. The Oxitec waste rock, Mesabi waste rock, birch mulch, and bark mulch project materials were observed to be more angular in structure than the corn grit media, which tended to be more uniform and rounded in shape. Angular materials may be useful for providing additional traction. Organic materials were observed to be more porous than the inorganic materials and may be useful as a sorbent.

Table 1.4 SEM imaging example for the blended birch mulch organic material



Fifth Update March 25, 2022:

Since the last update, we determined the bulk density of the materials and compiled physical properties evaluated in a summary table which can be seen in Table 1.5 below. The bulk densities may be used to guide parameters like application rate/surface area coverage and storage volume for materials, particularly the organics for which testing could not determine a specific gravity value because of flotation. The lower bulk densities for organic material suggest a smaller mass of product needed to provide equivalent surface area coverage. This may help lower weight of transportation but may not change storage volume as dramatically. SEM imaging was used to qualify material angularity via Powers scale with higher angularity suggesting better friction potential. Sand and corn grit were determined as sub-rounded, and the remaining materials were determined as angular with the Mesabi waste rock being “very angular”. An update of the particle size distribution curve is included as Figure 1.5 which now includes a highlighted section of the recommended particle size range for abrasives in winter road maintenance. The corn grit material fell completely within the bounds of recommended particle size range and would not need to be filtered from particle sizes prior to application if used within this range, however its tenderness as an organic material has a higher potential for crushability when on the roadway which should be considered. Values for the materials' fineness modulus and coefficients of uniformity were also determined from the gradation curves in Figure 1.5. The corn grit and the waste rocks were uniformly graded meaning most of the material falls within a small range of particle sizes. Sand was non-uniformly graded. The fineness modulus was largest for the waste rocks, followed by the corn grit and then sand and is included as an index value to represent average particle size.

Table 1.5 Compiled physical properties of project material used to assess potential for application during winter maintenance.

Material	Fineness Modulus	Bulk specific gravity	Apparent specific gravity	Water absorption capacity (%)	Bulk density (g/cm^3)	Angularity
Corn grit	5.39	<1	<1	-	0.436	Sub-rounded
Bark mulch	-	<1	<1	-	0.148	Angular
Birch mulch	-	<1	<1	-	0.209	Angular
Waste rock (OX)	6.69	3.09	3.30	2.07	1.70	Angular
Waste rock (MES)	6.33	2.82	3.11	3.27	1.18	Very angular
EcoTraction™	-	-	-	-	0.842	Angular
Sand	3.86	2.75	2.83	1.00	1.67	Sub-rounded

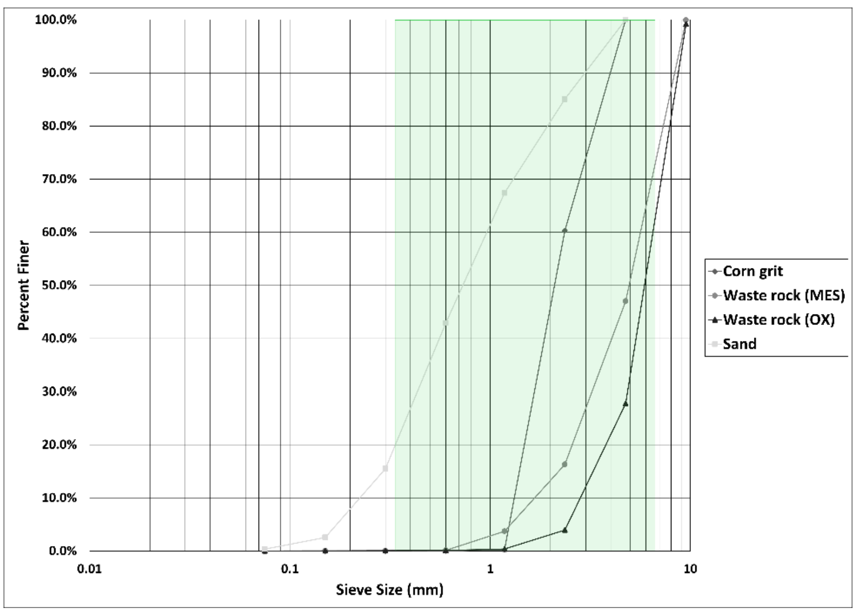


Figure 1.5 Particle size distribution curves for select project materials obtained through sieve analysis. The green portion represents the particle size range recommended by MnDOT for abrasive use: Sieve No.4-No.50 (4.75-0.3 mm).

Final Report Summary

This project investigated the potential of regionally available organic and inorganic industrial byproducts as alternatives to conventional sand and salts. Candidate materials include corn grit, timber waste, and taconite waste rocks local to Minnesota. Chemical and physical properties of the materials were characterized, including material elemental composition, morphology, particle size distribution, and specific gravity to establish a foundational understanding of the material. Material and chemical characteristics of the candidate materials indicate they have material features required for alternative abrasives and do not contain harmful metals. Particularly, angularity and darker color of iron minerals may provide better traction than sand and provide ice melting through insolation. Bio-based materials which has large surface area and fiber are expected to offer skid resistance as well as long lasting deicing efficacy when applied with deicing chemicals. The shape of abrasive materials may also be key factors for traction and deicing performance.

ACTIVITY 2 Title: ***Evaluation of traction and deicing efficacy and potential environmental impacts***
Description: Based on chemical and physical characteristics of the candidate materials in Activity 1, we will select the materials to meet properties of sanding/abrasive materials for winter road maintenance. The materials will be evaluated for traction and deicing efficiency and potential environmental impacts. For traction efficiency, skid resistance will be quantified on normal surface, ice and/or snow-covered surface for different types of road (e.g., asphalt, concrete, and gravel). The skid resistance will be tested through a portable friction test using British Pendulum test and texture measurement like sand patch method. The measurement will be conducted at various conditions to determine application rate, and frequency and weather condition will be recorded. Additionally, the durability of materials will be assessed by material loss upon different loading. We will perform laboratory tests to examine if the selective materials also enhance or inhibit deicing efficacies with the combination with chloride and non-chloride deicing chemicals. The deicing behavior will be evaluated by measuring a eutectic temperature and effective temperature for freezing/melting point and ice melting capacity based on Strategic Highway Research Program ice melting test methods. Additionally, solar absorbance of the materials will be tested using American Society of Testing Material Method E903 since greater solar absorbance can increase pavement surface temperature which results in the prevention of ice formation and enhancement of ice melting.

We will evaluate potential environmental benefits and impact of natural byproduct-based abrasives on soil/roadside vegetation, nearby water bodies, and air. Chemical analysis of leachate from the materials will be conducted. The chemical analysis includes trace metals, major anions, nutrient compounds (phosphorus-, nitrogen-, and sulfur compounds), and biochemical oxygen demand. Additionally, sorption experiments of common roadside contaminants (i.e., heavy metals, petroleum hydrocarbon, and chloride) with the selective candidate materials will be conducted to determine their sequestration capacity of the contaminants. As for organic materials, the breakdown materials collected from the durability test will be further evaluated for biodegradation rate and biochemical oxygen demand (BOD) loading. As for the impact of the materials on the air quality, silt generation will be examined using material loss measurement.

Collectively, preliminary recommendations will be developed for the application of natural byproducts as sanding/abrasive material in northeastern Minnesota based on the laboratory results and statistical analyses from Activity 2. The recommendations will be generated in consultation with St. Louis County and MnDOT District 1 based on current practice and equipment. The recommendations will include road types, storage and preparation (e.g. mixing and loading) of materials, application methods (e.g., pre-wetting and loading), and methods for the interception and recovery of sanding materials from reaching the watershed (e.g., stormwater grit chamber and holding ponds).

Outcome	Completion Date
1. Deicing efficacy and traction efficiency of natural byproduct-based abrasives determined	January 31, 2021
2. Potential environmental benefits and impacts evaluated	March 31, 2021
3. Preliminary recommendations made for the application of natural byproducts as abrasive material in Minnesota, in the form of a final report	June 30, 2021

First Update March 1, 2020
Materials for Activity 2 will be selected based on chemical and physical characteristics of the candidate materials in Activity 1. Meanwhile, the analysis scheme and flowchart have been developed to evaluate for traction and deicing efficiency and potential environmental impacts.

Second Update October 25, 2020
We have selected initial candidate materials based on Activity 1's result. The candidate materials have been tested as raw materials first. Some organic materials were modified as salt-binding abrasive materials which prepared by soaking them in MNDOT brine solutions. The dried salt-binding abrasive materials are tested as additional candidate materials. We have calibrated a British Pendulum test to measure the skid resistance upon application of candidate materials. We have evaluated friction level of different pavements as reference point. As winter season approaches, we have designed testing matrix to evaluate friction enhancement by candidate abrasives materials in field sites (asphalt parking lot and concrete pavement) at three application rates including MNDOT's recommendation rate. During the friction test, we have evaluated deicing capacity by measuring temperature gradients on payment with applied abrasives using a thermal imaging camera. Currently, we are also performing material loss by friction to assess the durability of materials for mineral-based materials. This experiment will also inform silt generation by friction. We just started chemical leaching experiments for mineral-based materials with synthetic rainwater and weak acid solution. The leachate will be analyzed for cations, anions, and total organic carbons.

Third Update March 25, 2021
Based on the Activity 1's results, 5 candidate raw materials including two iron rock wastes and three organic materials, a corn grit and two bark mulches were selected for deicing, skid resistance and environmental leaching experiments along with reference materials. All tests were conducted with the candidate materials with 0.3-4.75 mm. The skid resistance tests were conducted on ice sheets in the lab and on iced pavements in the field using the British Pendulum Skid resistance tester (Photos of lab and field tests in Figure 2.1). The dosage rate for the skid resistance test was decided based on MnDOT recommendations (communication with MNDOT officials). Initial tests were conducted on ice sheets with a dosage rate of 2.5 g/ft^2 to determine the probable dosage rate range for the field tests. The skid resistance values on ice sheet in the lab were 10-20 depending on surface temperature and melting. When the candidate materials were applied on ice sheets, the skid resistance improved to over 30 for mineral materials (e.g. oxitate). In the field, we conducted the skid resistance teste on bare pavement without snow or ice covers and observed 70-80 and 80-120 of skid resistance values for asphalt and concrete pavement, respectively. The values decreased down to 30-50 varied by ice thickness and coverage. Improvement of skid resistance by the candidate materials varied but candidate mineral materials showed similar or better skid resistance in comparison to MnDOT reference materials. MnDOT recommended skid resistance value for pavement is generally greater than 50 (personal communication).

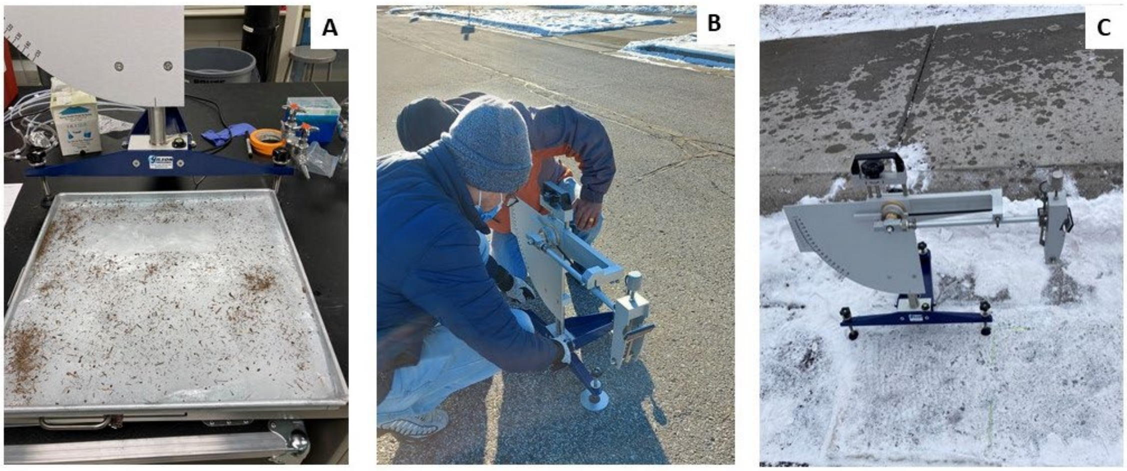


Figure 2.1 Photos of British Pendulum Skid resistance testing with and without the candidate and reference materials on (A) ice sheet in the lab, (B) bare asphalt pavement, and (C) asphalt

Preliminary analysis of environmental leachate was designed to develop a proper method for the environmental impact assessment of candidate materials. Each material was exposed to deionized water (MilliQ water) as a function of time (1-hour, 1-day, 1-week and 1-month). Parameters analyzed include pH, conductivity, dissolved oxygen (DO), turbidity, and crude concentration of organic matters (absorbance at 335 nm). Figure 2.2 shows preliminary dissolved oxygen and turbidity of leachate as a function of time. Overall, DO level decreased after 1 weeks and the largest DO drop was observed in corn grit leachate suggesting potential microbial degradation of corn grit. Presumably, increasing turbidity in corn grit leachate may also result from microbial degradation of corn grits. Additional experiments of leachate analysis are in progress. Moreover, a sorption experiments of common roadside contaminants (i.e., heavy metals, petroleum hydrocarbon, and chloride) with the selective candidate materials will be conducted to determine their sequestration capacity of the contaminants. These results will assist in determining which parameters to evaluate further and additional parameters to add to the evaluation.

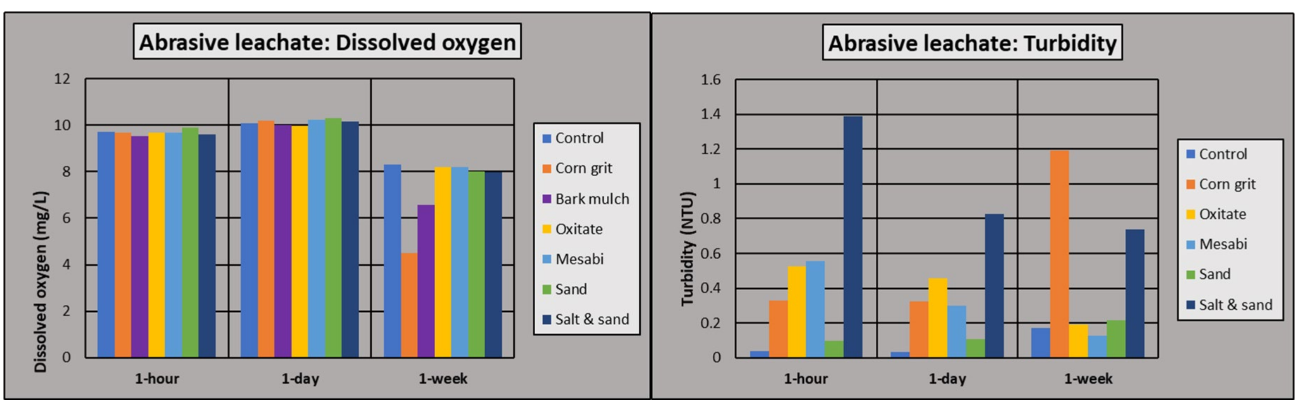


Figure 2.2 Preliminary abrasive leachate results for dissolved oxygen and turbidity parameters for candidate abrasive material and MnDOT reference material.

Fourth Update October 25, 2021:

In-lab study of material skid resistance has been completed for asphalt and concrete surfaces and can be found in Figure 2.3. Concrete and asphalt road surface samples were provided by UMD civil engineering department. Results show that the organic and inorganic materials, except for corn grits, either meet or exceed current level of skid provided by MnDOT reference materials on test surfaces. The inorganic study materials performed better in terms of skid resistance when compared to organic study materials and show more potential for use as an abrasive in the final composite.

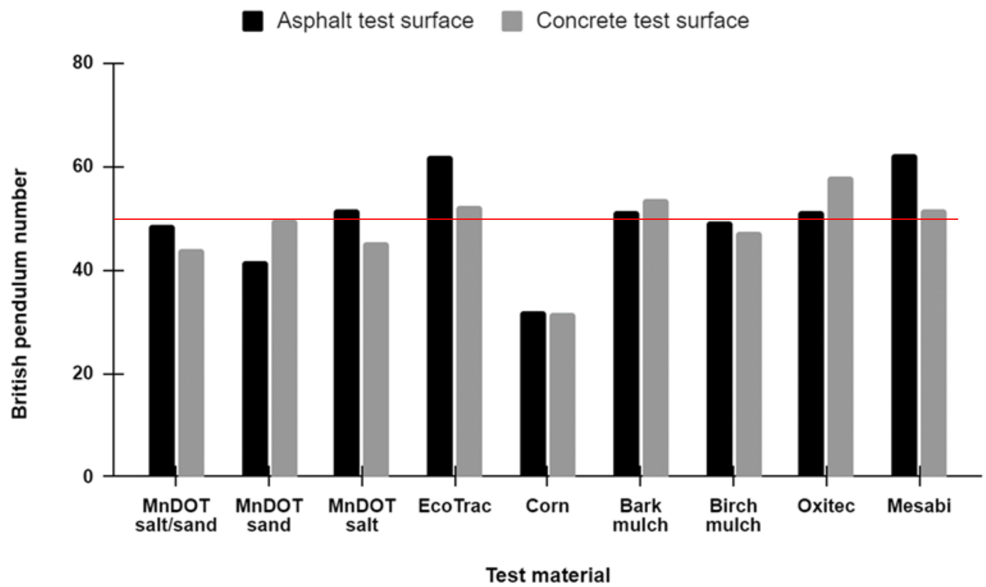


Figure 2.3 Test material British Pendulum Number (BPN) results from skid resistance tests. BPN of 50 is shown in red to represent an arbitrary recommended safety threshold. Note that BPN values can be converted to coefficient of friction (COF) values through division by 100. Margin of error equal to or less than 2 BPN for all tests.

Evaluation of deice capacity has been completed for all raw project materials. Findings show that only MnDOT salt and salt/sand mixture have ice-melting capacity. Deice tests will continue for brine-soaked material and will be compared to MnDOT reference materials. Additional evaluation of ice melt conductivity and chloride content will be performed to compare differences in chloride release between the brine-soaked materials and the reference materials.

In order to evaluate environmental impacts of these alternatives, we have conducted material leachate analysis and sorption capacity of roadside contaminants. Leachate evaluation of materials exposed in distilled water and lake water is currently in progress and is projected to be completed by December. A liquid to solid ratio of 20:1 (mL:g) was chosen for the final analysis. Time intervals for analysis are 1-day, 1-week, 2-weeks, and, depending on leachate plateau and stabilization, 1-month. Samples have been taken and analyzed for pH, temperature, conductivity, dissolved oxygen, turbidity, phosphorus, nitrogen, total organic carbon, chemical oxygen demand, and select anions and cations.

Evaluation of material sorption capacity has started and is projected to be completed at the end of November. Chosen contaminants include copper, lead, sodium chloride and benzene. Copper experiments have been completed and no material was observed to have copper sequestration capabilities. Chloride experiments are ongoing and will be followed by lead, and finally benzene contaminants.

Alternative material formulation/composite will begin in November and mixtures will undergo a final evaluation of deice capacity and skid resistance as compared to MnDOT reference materials.

Fifth Update March 25, 2022:
Since the last update we have finished the remaining tasks for Activity 2 which included a comprehensive evaluation of the potential for material leachate to influence various freshwater quality indicator parameters, evaluation of material sorption/removal potential for various common roadside contaminants, and creation/deice evaluation of material infused with conventional deicer brine.

The salt infused material was made by soaking the material in conventional salt brine (23.3% NaCl) for several days, draining the brine, and then drying the soaked material. Data was collected to determine a mass balance for the infusion with expectations that the organics would contain a larger quantity of salt in the final product. Results from the mass balance can be visualized in Figure 2.4. As expected, the organics had a larger capacity for holding on to both wet and dried brine with the mulches retaining the largest salt content.

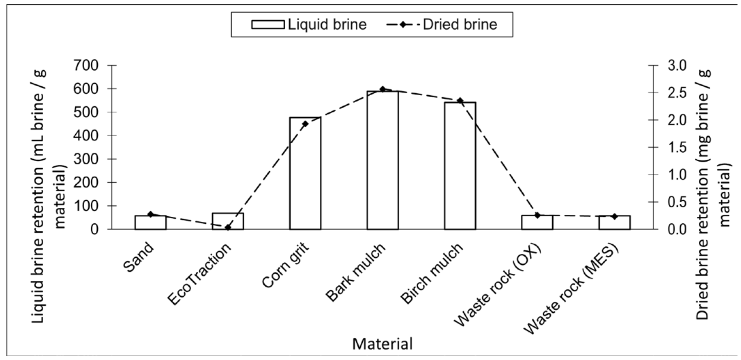


Figure 2.4 Salt retention of project materials for both wet (liquid brine) and dry (dried brine) conditions collected during infusing material with salt brine. The organic materials (corn grit, bark mulch, birch mulch) had the largest retention/storage capacity for the brine in both wet and dry conditions which can be attributed to their more porous nature.

The infused materials were then tested against conventional deicers, salt and salt/sand mixture, for deicer performance. Salt dosage was derived from the mass balance recorded during formulation and application rates were standardized to MnDOT's current application rates. This resulted in varying surface area coverage for the lighter materials versus the heaver materials. Deicer performance was evaluated through collecting the volume of ice melted over a seven-hour test period at 25°F, however for the corn grit the final volume was less than the total ice volume meaning that the corn grit had recaptured the melt. For the remaining deicers that did not fully melt with time, the ice melt volume is considered an approximation for the bark and birch mulches because their resorption of the ice melt could not be determined through the test procedure. The inorganics are likely close enough to their true performance because of their lesser sorption capabilities. Deicer performance results can be seen in Figure 2.5 below.

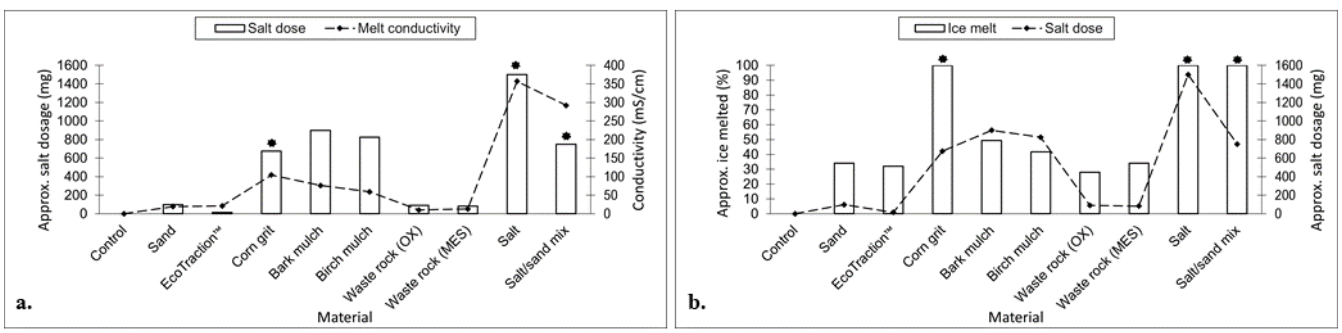


Figure 2.5 Brine infused material deicer performance results for (a) salt dosage of brine infused material at the standardized application rate vs percent ice melted and (b) vs conductivity of the ice melt, over a 7-hour deicer test period and controlled 25°F temperature. Star symbol is shown above data to indicate complete ice melt over the test period. Results show complete ice melt for conventional salt and salt/sand mixture as well as for the brine infused corn grit. The use of the corn grit deicer resulted in ice melt with less salt application, resorption of salty ice melt, and resulting lower conductivity of collected ice melt when compared to conventional deicer and deicer mixture.

Environmental leaching tests were performed over several time intervals to assess leachability. Batches were made by spiking a high concentration of material into pure, deionized water (20 mL per gram of material) and time intervals tested for were 1 day, 2 days, 1 week, and three weeks. Upon sampling, the leachate was measured for pH, dissolved oxygen (DO), conductivity, temperature, turbidity, and alkalinity. Collected samples were later analyzed for total phosphorus (TP), total nitrogen (TN), total organic carbon (TOC), common anions, and cations. Results are communicated as changes between the control leachate (pure, deionized water and no material addition) and material leachate at the longest timer interval, 3-weeks. Sample results can be found in figure 2.6 for pH, TOC, turbidity, and TN parameters. Acidification was observed for corn grit and birch mulch while alkalization was observed for the remaining material. Alkalization was most significant for sand leachate and acidification was most significant for corn grit leachate. Increase in total organic carbon concentration was highest for the organic material leachates, with corn grit being the largest concentration change, and was minor (<5 mg/L) for the remaining materials. Increases in total phosphorus concentration were highest for organic materials leachates, with corn grit again being the largest concentration change. Additionally, leachate for the Oxitec waste rock and EcoTraction™ were observed to have a noticeable (2-3 mg/L) increase as well when compared to the control. Increases in turbidity is one of the main environmental concerns with winter maintenance abrasive use was highest for the Oxitec waste rock with increases up to 1800 NTU.

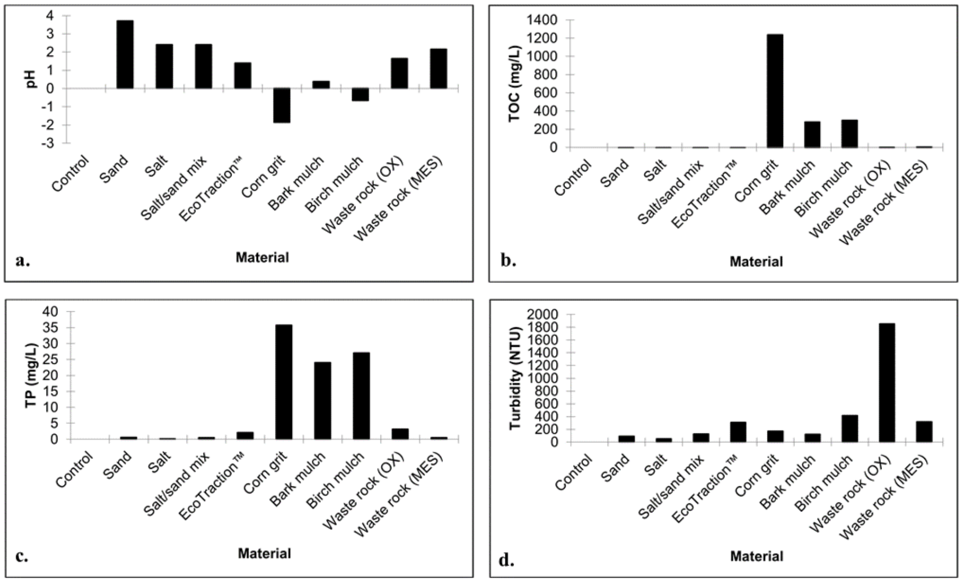


Figure 2.6. Material leachate results for the water quality parameters: (a) pH, (b) TOC, (c) TP, and (d) turbidity on the 3-week leaching period. Results are shown as deviations from the control.

Sorption experiments were performed on the project material to evaluate their sorption/removal potential for a variety of common roadside contaminants. Representative contaminants were chosen from three categories: (1) heavy metals, (2) organic hydrocarbons, and (3) winter maintenance contaminants. Lead and copper were tested as the heavy metals, benzene was tested as the hydrocarbon, and chloride was tested as the winter maintenance contaminant. Contaminant concentrations were selected based on environmentally relevant concentration ranges. Sorption capacity was not observed for copper or chloride at the concentration levels tested for any of the tested materials. Sorption capacity was observed for benzene and lead contaminants and can be found in figure 2.8 as representative linear K_d values. The mulches performed the best in terms of contaminant sequestration. The waste rocks were observed to have some sorption capabilities for the lead heavy metal contaminant testing and only the Mesabi sourced waste rock demonstrated sorption for benzene out of the two waste rocks.

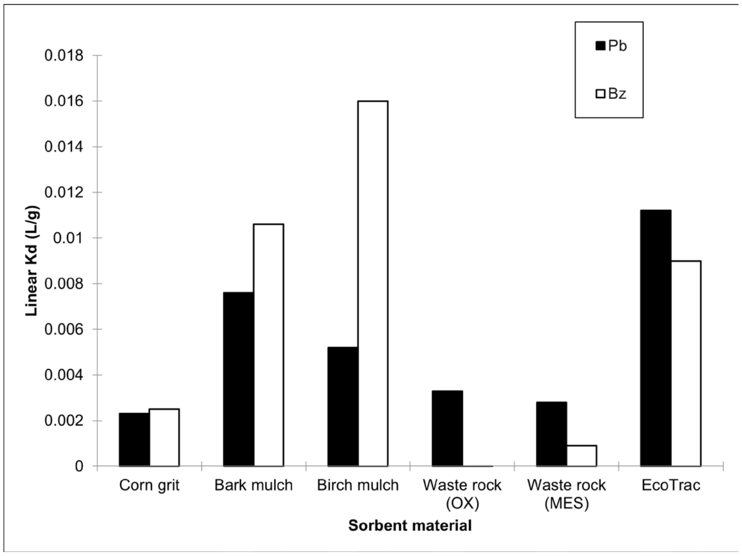


Figure 2.7. Sorption capacity performance of tested project materials shown as linear K_d (L/g) values for lead and benzene contaminants.

Final Report Summary

Based on material characteristics of the candidate materials, skid resistance and deicing tests with environmental impact assessment were performed to evaluate traction effectiveness and material safety. The results showed potential for bio-based materials such as corn grit and bark mulch as a sorbent for salt brine deicer with less salt impact and for the waste iron-bearing minerals to be used as effective abrasives in the realm of winter road maintenance. The use of alternative materials for winter road maintenance show promise for lower environmental impact, lower/controlled chloride pollution, increased friction enhancement, and beneficial reuse of industry waste material. It is recommended that further research be done to evaluate the deicer effectiveness of the brine infused material within controlled field studies to enhance the understanding of its usage potential. It may also be useful to analyze the longevity of the material on the roadway in the pilot study to evaluate reapplication needs. Recommendations to DOTs include either the implementation or improvement of effective street sweeping practices to avoid potential hazards associated with these materials such as increased frequency of sweeping and/or the implementation of BMPs associated with clean-up (such as updated, more effective equipment). Material applications concerns with regards to parameters including material durability and environmental pollution may be addressed through application scale and cleanup protocol as important factors in determining impact, i.e., use on low vehicular speed roadways paired with road sweeping cleanup are predicted to have the best performance while minimizing environmental impact.

IV. DISSEMINATION:

Description: Findings will be disseminated and archived via reports to LCCMR, peer-reviewed publications, and presentations at conferences. A fact sheet that summarizes our findings will also be shared with state agencies, particularly MnDOT and MPCA. Several manuscripts will be written and submitted for publication in peer-reviewed journals. All publications resulting from this project will be made available through Open Access journal websites. In addition, we will develop educational materials and opportunities for community discussion about water quality and winter road maintenance. These activities will provide opportunities to engage school and community groups in small-scale projects and build community support for water resource protection. Moreover, these partners and researchers will take the results of our study into consideration as they make management decisions and will work with us to ensure that our data products and research papers reach a broad audience within their agencies.

The Minnesota Environment and Natural Resources Trust Fund (ENRTF) will be acknowledged through use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications per the ENRTF Acknowledgement Guidelines.

First Update March 1, 2020
There has not been any dissemination activities as the project just started.

Second Update October 25, 2020
We have discussed our research progress with MNDOT and consulting companies (e.g. Fortin Consulting) which are working on chloride impact mitigation focused project with counties in the state. Through the discussions, we also learned existing resources (Smart Salting Trainings or the smart salting assessment tool) for the development of preliminary recommendations for the application of natural byproducts as sanding/abrasive materials.

Third Update March 25, 2021
Since the last update, two outreach activities were conducted for 6th-12th graders and general audiences. In December, our project team held a discussion meeting with middle school students of Arcadia Charter School, Northfield, MN. We also created a video clip, Safe Roads and Healthy Water to present and discuss our project for achieving safe roads and healthy water using local materials for the UMD's STEM Discovery Day in March, 2021.

Fourth Update October 25, 2021:
Project summary and select project results were presented virtually at the Minnesota Water Resources Conference poster session on October 19th. Virtual presentation followed an open discussion/Q&A format between attendees and the presenter.

Fifth Update March 25, 2022:
On October 27th we presented a 5-minute summary of the research project at the annual NRRI research poster session. In December, we presented a seminar on the research project as a part of UMD's Civil Engineering department seminar series to students, professors, and colleagues. Additionally, we have discussed the research project with undergraduates interested in learning more about research focused on environmental sustainability and winter road maintenance.

Final Report Summary
The project findings have been disseminated via reports to LCCMR, master student's thesis and presentations at regional conferences (Minnesota Water Resources Conference and UMD seminar series). The project findings were shared with the public through public outreach activities for 6th-12th graders and general audience: engineering discussion with middle school students of Arcadia Charter School, Northfield, MN and a video clip, Safe Roads and Healthy Water to present and discuss our project for achieving safe roads and healthy water using local materials for the UMD's STEM Discovery Day. The final dissemination of the findings was through a graduate student, Caitlin Graeber's master thesis and public presentation. Currently, we are preparing a manuscript for scholarly journal.

V. ADDITIONAL BUDGET INFORMATION:

A. Personnel and Capital Expenditures: See attached budget spreadsheet.

Explanation of Capital Expenditures Greater Than $5,000: N/A

Explanation of Use of Classified Staff: N/A

Total Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation*:*

FTE per this project/appropriation

Enter Total Estimated Personnel Hours for entire duration of project: 2,912	Divide total personnel hours by 2,080 hours in 1 yr = TOTAL FTE: 1.4

Total Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: N/A

VI. PROJECT PARTNERS:

A. Partners outside of project manager's organization receiving ENRTF funding

B. Partners outside of project manager's organization NOT receiving ENRTF funding

Name	Title	Affiliation	Role
Duane Hill	District Engineer	MnDOT District 1	Providing consultation for winter road maintenance and strategies
Christopher Cheney	Maintenance Superintendent	MnDOT District 1	

VII. LONG-TERM- IMPLEMENTATION AND FUNDING:

This project aligns well with the state's collaborative efforts to reduce the amount of chloride entering the environment while still providing safe winter driving road conditions for Minnesota. A key project outcome will be the generation of essential information for developing best-use implementation strategies and guidelines. In the long term, this project will help to facilitate adoption of chloride management and mitigation practices and enhance sustainability of our economy and natural water resources in Minnesota.

VIII. REPORTING REQUIREMENTS:

- Project status update reports will be submitted March 1 and September 1 each year of the project
- A final report and associated products will be submitted between June 30 and August 15, 2022

IX. SEE ADDITIONAL WORK PLAN COMPONENTS:

Submit any additional work plan components or mark as N/A.

A. **Budget Spreadsheet**
B. **Visual Component or Map**
C. **Parcel List Spreadsheet** N/A
D. **Acquisition, Easements, and Restoration Requirements** N/A
E. **Research Addendum** N/A

Attachment A:
Environment and Natural Resources Trust Fund
M.L. 2019 FINAL Budget Spreadsheet
Legal Citation: M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04o
Project Manager: Chan Lan Chun
Project Title: Evaluating Locally-Sourced Sanding Materials for Road Salt Reduction
Organization: University of Minnesota
Project Budget: $162,000
Project Length and Completion Date: 3 years and June 30, 2022
Today's Date: Aug. 12, 2022

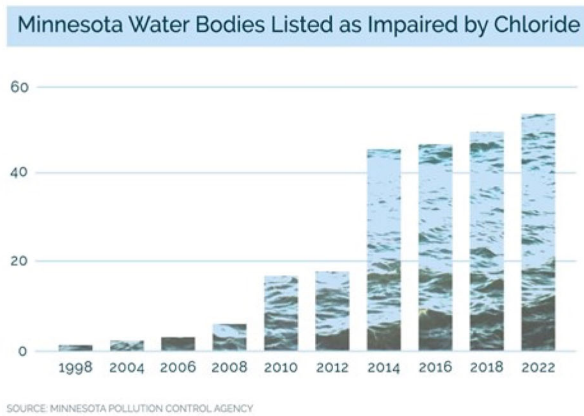
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget [04/25/2022]	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 132,024	$ 132,024	$ -
Chan Lan Chun, Principal Investigator: $23,568 (66.5% salary, 33.5% benefits); 7.4% FTE each year for 2 years			
Manik Barman, Co-investigator: $ 12,384 (66.5% salary, 33.5% benefits); 3.8% FTE each year for 2 year			
Larry Zanko, Co-investigator: $10,128 (66.5% salary, 33.5% benefits); 3.8% FTE each year for 2 year			
Graduate Student Research Assistant: $ 81,854 (15% benefits and tuition reimbursment in academic year); 50 % FTE in academic year and 50% FTE summer each year for 2 years			
Undergraduate Student Research Assistant: $ 2,590 (100% salary); 5% FTE each year for 2 year			
Equipment/Tools/Supplies			
Laborabory supplies ($15,000): Chemical, thermal control and expendable lab supplies (e.g. plasticware, bottles, columns, disposable labware) and field test supplies ($8,000): Friction tester (British Pendulum tester) and expendable supplies	$ 25,500	$ 25,499	$ 1
Printing			
Printing and copy for factsheet and communication	$ 13	$ 13	$ 0
Travel expenses in Minnesota			
Sample collection, meeting with state agency, and field testing : ~2000 miles x$0.55/mi =$1,100 + vehicle rental use $10/day x 10days=$100	$ 133	$ 133	$ -
Other			
Chemical, mineralogical, and microscopic analyses: University of Minnesota Research Analytical Lab: SEM-EDX($34/hr, 70 hrs), XRD($15/hr, 50 hrs), ICP($26/sample, ~100 samples), and nutrient analysis ($64/sample, ~20 samples)	$ 4,330	$ 4,330	$ -
COLUMN TOTAL	$ 162,000	$ 161,999	$ 1

OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)		Spent	Balance
In kind: Unrecovered indirect: 54% modified total direct cost ($131,566 base; excludes graduate student tuition)	Secured	$ 131,566	$ 131,566	$ -

PAST AND CURRENT ENRTF APPROPRIATIONS	Amount legally obligated but not yet spent		Spent	Balance
Current appropriation:			$ -	
Past appropriations:			$ -	

Reducing environmental impacts of chloride on watersheds through the reduction of road salt use and utilizing byproduct materials as a green option

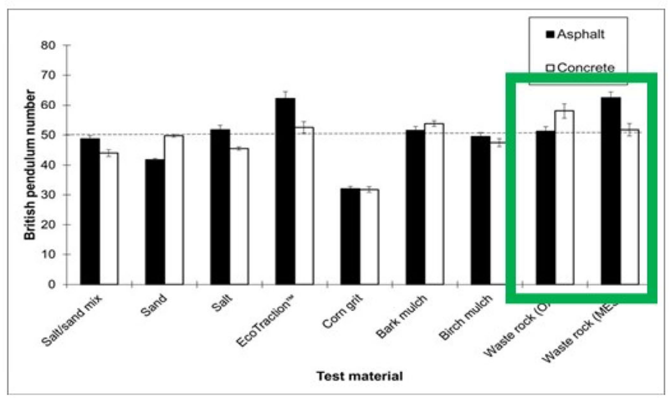
Environmental Impacts of Chloride by Winter Road Maintenance



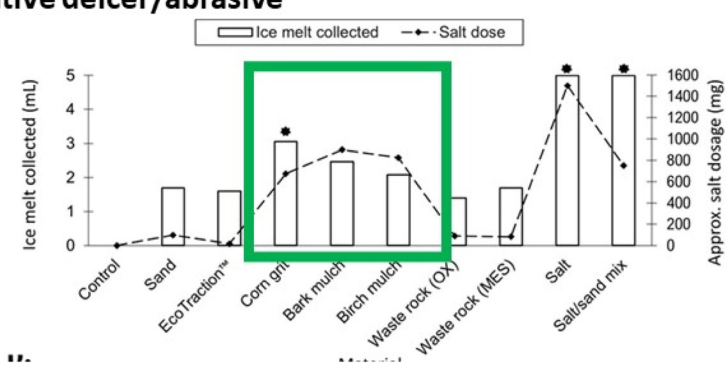
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Can natural byproducts be used as alternative abrasives for chloride reduction to protect our watershed?

Greater potential for use as abrasive



Brine infused bio-based materials for alternative deicer/abrasive



The outcomes of the project will help to facilitate adoption of chloride management and mitigation practices, leading sustainability of our economy and protecting water resources in Minnesota.