Environment and Natural Resources Trust Fund

2022 Request for Proposal

General Information

Proposal ID: 2022-230

Proposal Title: Managing Highly Saline Waste From Municipal Water Treatment

Project Manager Information

Name: Natasha Wright

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: We aim to develop a cost- and energy-efficient method of managing concentrated saline waste from municipal desalination plants, increasing the economic feasibility of centralized water softening and sulfate removal.

Funds Requested: $266,000

Proposed Project Completion: June 30 2025

LCCMR Funding Category: Water Resources (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.

Levels of chloride and sulfate (both salts) in Minnesota waterways is a growing concern due to the potential for harm to aquatic life (chloride) and the quality of water used for growing wild rice (sulfate). Increased chloride comes from multiple sources including salt used for winter road maintenance, residential and commercial water softeners, industry, and agriculture. Sulfate also has multiple sources to surface water, including industrial waste, domestic waste, and use of groundwater for agricultural, industrial, and domestic needs. Because WWTPs are not equipped with the technology to remove dissolved salts, chloride and sulfate that enter these facilities end up back in waterways.

An opportunity exists to reduce this discharge to waterways by installing centralized water softening and desalination technology (such as reverse osmosis, RO) at the municipal scale. Doing so, however, results in a liquid waste stream that contains all the removed contaminants in highly concentrated form; this waste stream has to be treated and properly disposed of, which is expensive. A recent ENTRF-funded report to analyze sulfate treatment options indicates that brine management would represent >46% of the total capital cost and >81% of the operational cost of a newly installed RO system at sample POTWs (MPCA, 2018).

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

While inland treatment plants using RO typically inject this concentrated waste into deep wells, evaporate the remaining water in large evaporation ponds, or use an evaporative crystallizer, none of these methods are viable for treatment plants in Minnesota. All three are far too expensive and standard evaporation ponds require too much land area, especially given the seasonal climate variation (temperature and humidity) in Minnesota.

One method that could be used to reduce the capital and energetic cost of brine management is convection enhanced evaporation (CEE). An example of CEE is Wind Aided Intensified eVaporation (WAIV), a system that utilizes hanging vertical sheets to increase the evaporative surface area for a given area of land (Gilron, 2003). Initial calculations show that CEE could reduce the land area required by at least 30 times versus standard evaporation ponds, while avoiding the high capital cost and fuel required for a crystallizer. However, a number of questions remain about the optimal physical design, ideal material properties for the evaporation surfaces, and how precipitated salts could be removed from the sheets. Our goal is to answer those questions – and in the future, be able to reuse the precipitated salts for practical purposes.

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 target project outcome of our research will be a cost- and energy-efficient system for managing the brine (concentrated salt-laden liquid waste) from membrane-based water treatment plants at the municipal scale. This will increase the economic feasibility of utilizing reverse osmosis for centralized water softening and treatment, thereby substantially reducing the addition of chloride, sulfate, and other contaminants to Minnesota waterways.

Activities and Milestones

Activity 1: Develop model for how the highly concentrated salt brine evaporates from various evaporation surfaces

Activity Budget: $131,000

Activity Description:
Previous models from our team and models in the literature will be extended to include the evaporative behavior of highly concentrated industrial and desalination brines. This model will be validated using a lab-scale experimental setup in simulated conditions to quantify the predictive capability of the model. Modeling will include natural, forced, and mixed convection scenarios, vertical sheets and horizontal trays, and parallel flow, counter-flow, and co-flow arrangements.

Activity Milestones:

Description	Completion Date
1. Develop integrated model of CEE for vertical and horizontal surfaces in parallel flow	December 31 2022
2. Validate vertical surface, parallel flow model using in-lab prototype under simulated conditions	June 30 2023
3. Develop integrated model of CEE for counter-flow and co-flow arrangements.	December 31 2023

Activity 2: System optimization and MN-based piloting

Activity Budget: $135,000

Activity Description:
Once we have a predictive model, we will analyze the parametric relationships between design variables (for example water composition, ambient temperature and humidity, surface tension, surface orientation, flow configuration). We will use this understanding to perform multi-objective design optimization, focused on reducing cost and energy consumption. A small pilot-system will be prototyped and tested under simulated conditions in the lab.

Activity Milestones:

Description	Completion Date
1. Understanding of parametric relationships between system variables	June 30 2024
2. Develop theory for an optimized system design	December 31 2024
3. Pilot system tested under simulated conditions and techno-economic assessment for a MN WWTP prepared.	June 30 2025

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Catherine Neuschler	Minnesota Pollution Control Agency	The MPCA continues to be interested in centralized water softening and treatment. Their staff will help us understand cost barriers and determine common operating points (flow rates, water quality parameters), enabling us to optimize and provide case studies on benefits achieved through this technology.	No

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 be funded?
We continue to pursue National-scale funding for this project. We have received funds through the Bureau of Reclamation to pilot an alpha prototype of the proposed system using horizontal evaporative surfaces in New Mexico. We also hope to work with a team at the Carlson School of Management to determine realistic value propositions for the technology as part of Activity 2, Outcome 3 (MN-based techno-economic assessment).

Project Manager and Organization Qualifications

Project Manager Name: Natasha Wright

Job Title: Assistant Professor

Provide description of the project manager's qualifications to manage the proposed project.
Richard & Barbara Nelson Assistant Professor in the Department of Mechanical Engineering at the University of Minnesota – Twin Cities

B.S., Mechanical Engineering, 2012, University of St. Thomas, St. Paul, MN
S.M., Mechanical Engineering, 2014, Massachusetts Institute of Technology, Cambridge, MA
PhD, Mechanical Engineering, 2018, Massachusetts Institute of Technology, Cambridge, MA
Post-Doctoral Associate, Environmental Engineering, 2019, University of Minnesota

Dr. Natasha Wright will be responsible for the overall project coordination. Her research focuses on the design of decentralized desalination (salt removal) systems, with a specialty in membrane-based separation processes and their pairing with renewable energy sources. Over the last 9 years, she has piloted combined energy generation / water treatment systems in the United States, India, and Gaza. Recent work has focused on reducing the cost of small-scale desalination systems via the redesign of system sub-components. This work has resulted in numerous design awards including Forbes 30 Under 30 and the Lemelson Prize at MIT, two patents, and several papers in the field of Desalination.

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://www1.umn.edu/twincities/01_about.php). The laboratories and offices of the PI contain all of 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								
Project Manager		Project coordination, guide development of model extension, supervise graduate students. 1 month/year, 3 years, including UMN rate of 36.5% benefits.			27%	0.24		$46,860
Graduate Research Assistant		Analytical model extension, prototype design, fabrication, and testing. Includes UMN rate of 19.9% benefits plus tuition.			43%	1.5		$158,321
Undergraduate Researcher		Assist with prototyping and data collection system. 2 students for 10 hours/wk at $12/hr.			0%	0.5		$12,480
							Sub Total	**$217,661**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Tools and Supplies	Prototyping materials, consumable supplies, labortary notebooks, sensors and data aquisition equipment, operating costs for laboratory instruments required for analyses and experiments	Tools and supplies required to prototype the brine evaporation system and to collect the data necessary for data validation.					$40,339
							Sub Total	**$40,339**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								

	Miles/ Meals/ Lodging	University vehicle rental, hotel/meal charges	Site visits with WWTPs and other local stakeholders					$1,000
	Conference Registration Miles/ Meals/ Lodging	Conference Presentation	Attendance at local conferences to disseminate project findings.					$2,000
							Sub Total	**$3,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Publications charges (x2)	To make published journal articles immediately available via open access to maximize data availability and dissemination					$5,000
							Sub Total	**$5,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$266,000**

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				
In-Kind	University of Minnesota	Because the project is overhead free, laboratory space, electricity, and other facilities/administrative costs (55% of direct costs excluding permanent equipment and graduate student tuition benefits) are provided in-kind.	Secured	$119,016
			Non State Sub Total	**$119,016**
			Funds Total	**$119,016**

Attachments

Required Attachments

Visual Component

File: 47e038f8-07e.pdf

Alternate Text for Visual Component

Image shows current option for concentrate management from municipal treatment is prohibitively cost and energy intensive. Diagram of alternative treatment method....

Optional Attachments

Support Letter or Other

Title	File
Letter of Support - MPCA	4071bb42-39f.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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

Yes

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

Yes

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

No

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

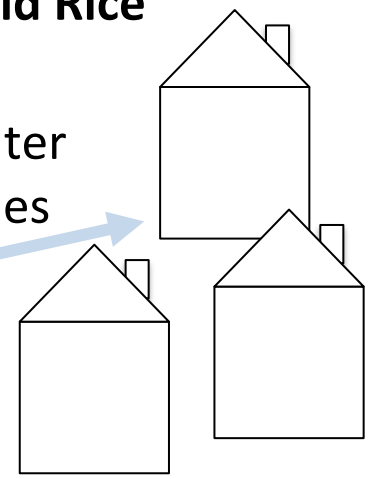
Yes, Sponsored Projects Administration

Protecting Minnesota Waterways, Aquatic Life, and Wild Rice

salty input water

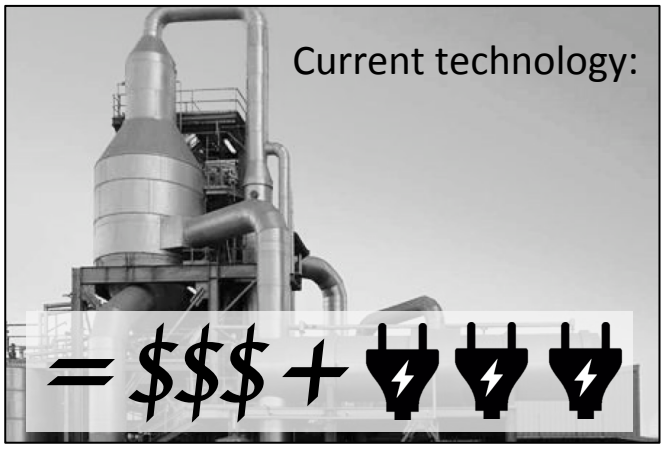
Centralized water softening and sulfate removal with **proven technology**: reverse osmosis (CCRO)

soft water to homes



no need for home water softeners that add chloride to our waterways

concentrated saltwater (liquid waste)



Proposed technology:

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