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

Project Title: **ENRTF ID: 080-B**

Managing Highly Saline Waste from Municipal Water Treatment

Category: B. Water Resources

Sub-Category:

Total Project Budget: $ 255,000

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

Summary:

We will develop a cost- and energy-efficient method of managing the concentrated saline waste from a municipal desalination plant, increasing the economic feasibility of centralized water softening and sulfate removal.

Name: Natasha Wright

Sponsoring Organization: U of MN

Job Title: Dr.

Department: Mechanical Engineering

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Minneapolis MN 55391

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Email wrigh677@umn.edu

Web Address:

Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

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

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

PROJECT TITLE: MANAGING HIGHLY SALINE WASTE FROM MUNICIPAL WATER TREATMENT

I. PROJECT STATEMENT

Our goal is to develop a **cost- and energy-efficient method of 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.**

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 the 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 the chloride and sulfate discharge to waterways by installing centralized water softening and desalination technology at the municipal scale. Utilizing reverse osmosis (RO) would allow for the removal of hardness, in addition to other contaminants, such as sulfate, heavy metals, and other emerging contaminants that can be harmful to the environment. RO is a pressure driven technology in which a pump is used to pressurize the feed water and force it through a semi-permeable membrane. Recent innovations in the RO process have decreased water wastage to less than 10%. 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 LCCMR-funded report commissioned by the MPCA[1] to analyze sulfate treatment options states:

Of the technologies reviewed, reverse osmosis (RO) and nanofiltration (NF), both membrane technologies, were identified as the most promising, well-established technologies for sulfate removal. Part 1 also stated that ***further research and development on cost-effective means for managing the salt-laden, liquid waste generated by these processes is needed.***

The report 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.[1] 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 take up too much land area, especially given the seasonal climate variation (temperature and humidity) in Minnesota.

One potential technology that could be exploited to reduce the capital and energetic cost of brine management 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.[2] Initial calculations show that WAIV 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 surrounding how the brine would be circulated, ideal material properties for the hanging sheets, how precipitated salts could be removed from the sheets, and the low cost construction and maintenance of such an enhanced evaporation system. Our goal is to answer those questions – and in the future, be able to **reuse the precipitated salts for practical purposes**.

[1] Minnesota Pollution Control Agency. Analyzing Alternatives for Sulfate Treatment in Municipal Wastewater. May 2018.
[2] Gilron *et al.* Wind Aided Intensified Evaporation for Reduction of Desalination Brine Volume. *Desalination,* 158, 2003.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1 Title: *Develop model for how the highly concentrated salt brine evaporates from the hanging sheets*
Description:
Models in current literature will be extended to include the evaporative behavior of highly concentrated brines and coupled to another model that describes the interaction between the concentrated brine and the evaporative material. This model will be validated using a lab-scale experimental setup in simulated conditions to quantify the predictive capability of the model.
ENRTF BUDGET: $ 122,000

Outcome	Completion Date
1. Understand the fundamental equations government evaporation of highly saline brines	*12/31/2020*
2. Develop integrated model of enhanced evaporation from hanging sheet	*6/30/2021*
3. Validate model using in-lab prototype under simulated conditions	*12/31/2021*

Activity 2 Title: *System optimization and piloting*
Description:
Once we have a predictive model, we will analyze the parametric relationships between various variables (for example water composition, ambient temperature and humidity, surface tension). 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.
ENRTF BUDGET: $ 133,000

Outcome	Completion Date
1. Understanding of parametric relationships between system variables	*6/30/2022*
2. Optimized system design realized theoretically	*12/30/2022*
3. Pilot system tested under simulated conditions	*6/30/2023*

III. PROJECT PARTNERS AND COLLABORATORS:

This project has the support of the Minnesota Pollution Control Agency, due to their continued interest in centralized water softening and treatment. We plan to communicate with their staff and municipal water supplies to understand cost barriers and to determine common operating points (flow rates, water quality parameters), enabling us to optimize and provide case studies on benefits achieved through this technology.

IV. LONG-TERM IMPLEMENTATION AND FUNDING:

We will pursue National-scale funding for this project through the Bureau of Reclamation. We also hope to work with a team at the Carlson School of Management to determine realistic value propositions for the technology.

Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Natasha C. Wright
Project Title: Managing highly saline waste from municipal water treatment
Organization: University of Minnesota
Project Budget: $ 255,000
Project Length and Completion Date: 3 years, 6/30/2023
Today's Date: 4/10/2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 212,000	$ -	$ 212,000
Professor Natasha Wright, Project Manager (74% salary, 26% fringe benefits). 8% FTE for years 1-3. Project coordination, Guide development of model extension. Supervision of graduate researchers. $46,000			
Graduate student Research assistant, analytical model extension, system prototyping and testing (59% salary, 41% fringe benefits) 50% FTE for years 1-3. $153,500			
Undergraduate researchers (x2). Assist with prototyping and data collection of prototype system. 10 hrs per week for one academic year. (100% salary) $12,500			
Professional/Technical/Service Contracts			
	$ -	$ -	$ -
Equipment/Tools/Supplies			
Prototyping Materials ($14,000 total). Supplies: consumable supplies, laboratory notebooks ($2,000 total). Sensors and data aquisition equipment for model validation ($15,000 total). Operating costs for laboratory instruments required for analyses and experiments; costs portioned based on usage by project ($4,000 total)	$ 35,000	$ -	$ 35,000
Capital Expenditures Over $5,000			
	$ -	$ -	$ -
Fee Title Acquisition			
	$ -	$ -	$ -
Easement Acquisition			
	$ -	$ -	$ -
Professional Services for Acquisition			
	$ -	$ -	$ -
Printing			
	$ -	$ -	$ -
Travel expenses in Minnesota:			
Charges and university vehicle rental for trips to WWTPs and other local stakeholders. Hotel/meal charges if overnight stay required. Attendence for students at local conferences to disseminate project findings. Reimbursement will be according to University of Minnesota guidlines.	$ 3,000	$ -	$ 3,000
Other:			
Publication charges to make published journal articles (2-3) immediately available via open access to maximize data availability and dissemination.	$ 5,000	$ -	$ 5,000
COLUMN TOTAL	$ 255,000	$ -	$ 255,000

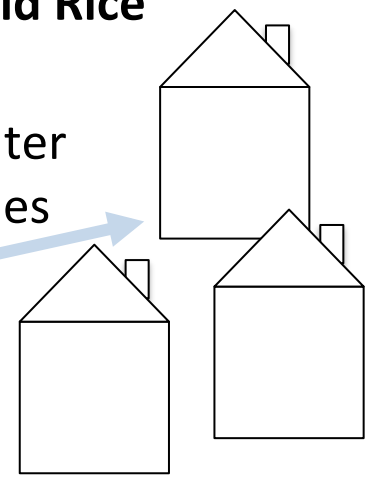
SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State:		$ -	$ -	$ -
State:		$ -	$ -	$ -
In kind: Because the project is overhead free, laboratory space, electricty, and other facilities/adminstrative costs (54% of direct costs excluding permanent equipment and graduate student tuition benefits) are provided in-kind.	*secured*	$ 112,000	$ -	$ 112,000
Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	**Amount legally obligated but not yet spent**	**Budget**	**Spent**	**Balance**
		$ -	$ -	$ -

Protecting Minnesota Waterways, Aquatic Life, and Wild Rice

salty input water

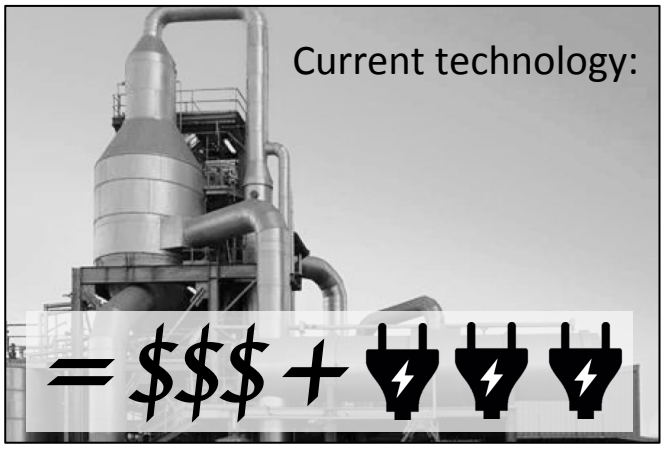
Centralized water softening and sulfate removal with **proven technology**: reverse osmosis (CCRO)

soft water to homes



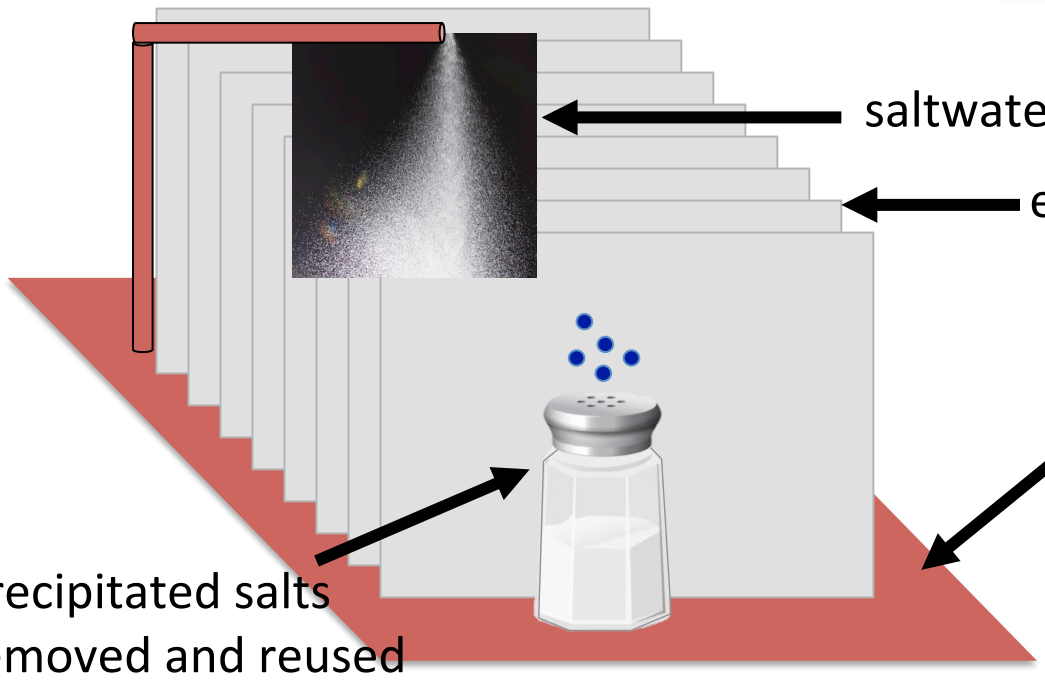
no need for home water softeners that add chloride to our waterways

concentrated saltwater (liquid waste)



Proposed technology:

= $ +



Project Manager Qualifications and Organization Description

Natasha C. Wright
Richard & Barbara Nelson Assistant Professor in the Department of Mechanical Engineering at the University of Minnesota – Twin Cities (starting December 2019)

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 7 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 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.