Environment and Natural Resources Trust Fund (ENRTF)

M.L. 2020 ENRTF Work Plan

Today's Date: August 22, 2019

Date of Next Status Update Report: April 1, 2021

Date of Work Plan Approval:

Project Completion Date: June 30, 2023

Does this submission include an amendment request? No

PROJECT TITLE: MANAGING HIGHLY SALINE WASTE FROM MUNICIPAL WATER TREATMENT

Project Manager: Natasha C. Wright

Organization: University of Minnesota

College, Department, or Division: Mechanical Engineering

Mailing Address: Mechanical Engineering Building, 111 Church St SE, Minneapolis, MN 55455

City, State, Zip Code: 55455

Project Manager Direct Telephone Number: 612-219-3540

Email Address: wrigh677@umn.edu

Web Address: N/A

Location: Minneapolis, MN 55455 and Statewide

Total Project Budget: $250,000

Amount Spent: $0

Balance: $250,000

Legal Citation: M.L. 2020, Chp. xx, Sec. xx, Subd. xx

Appropriation Language:

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 wastewater treatment plants (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. [The report] 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 publicly owned treatment works (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. OVERALL PROJECT STATUS UPDATES:

First Update March 1, 2021

Second Update September 1, 2021

Third Update March 1, 2022

Fourth Update September 1, 2022

Fifth Update March 1, 2023

Final Report between project end (June 30) and August 15, 2023

III. 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.

Activity 1 ENRTF BUDGET: $ 119,000

Outcome	Completion Date
1. Understand the fundamental equations governing the 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*

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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.

Activity 2 ENRTF BUDGET: $ 131,000

Outcome	Completion Date
1. Understanding of parametric relationships between system variables	*6/30/2022*
2. Develop theory for an optimized system design	*12/30/2022*
3. Pilot system tested under simulated conditions and techno-economic assessment for a MN WWTP prepared.	*6/30/2023*

First Update March 1, 2021

Second Update September 1, 2021

Third Update March 1, 2022

Fourth Update September 1, 2022

Fifth Update March 1, 2023

Final Report between project end (June 30) and August 15, 2023

IV. DISSEMINATION:

Description:
The target audience for results from this research will be engineers and scientists in academia, professionals in the area of desalination and water treatment, city managers and other local government officials, industry and trade organization personnel (for example, the Minnesota Pollution Control Agency and Metropolitan Council Environmental Services (MCES). Results will be disseminated through scholarly publications in peer-reviewed journals such as *Desalination.* Results from the research project will also be presented at regional conferences such as the *Conference on the Environment* or the *American Water Works Association: Minnesota Section Annual Conference.*

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, 2021

Second Update September 1, 2021

Third Update March 1, 2022

Fourth Update September 1, 2022

Fifth Update March 1, 2023

Final Report between project end (June 30) and August 15, 2023

V. ADDITIONAL BUDGET INFORMATION:

A. Personnel and Capital Expenditures

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:

Enter Total Estimated Personnel Hours for entire duration of project: 2200	Divide total personnel hours by 2,080 hours in 1 yr = TOTAL FTE: 1.06

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

Enter Total Estimated Contract Personnel Hours for entire duration of project: N/A	Divide total contract hours by 2,080 hours in 1 yr = TOTAL FTE: N/A

VI. PROJECT PARTNERS:

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

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

This project has the support of the Minnesota Pollution Control Agency. We plan to communicate with their staff and municipal water suppliers 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. Neither will be funded as part of this project but will assist with dissemination.

VII. LONG-TERM- IMPLEMENTATION AND FUNDING:

We have been pursuing National-scale funding for the project and will continue to do so. We also hope to work with a team at the Carlson School of Management to determine realistic value propositions for the technology.

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, 2023

IX. SEE ADDITIONAL WORK PLAN COMPONENTS:

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

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: $250,000
Project Length and Completion Date: 3 years, 6/30/2023
Today's Date: 8/22/2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 210,000	$ -	$ 210,000
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) $10,500			
Professional/Technical/Service Contracts			
	$ -	$ -	$ -
Equipment/Tools/Supplies			
Prototyping Materials ($13,000 total). Supplies: consumable supplies, laboratory notebooks ($1,000 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)	$ 33,000	$ -	$ 33,000
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.	$ 2,000	$ -	$ 2,000
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	$ 250,000	$ -	$ 250,000

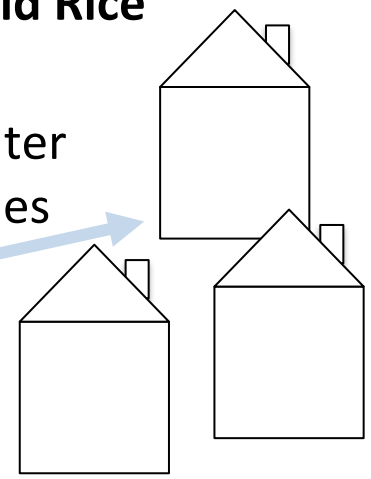
SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State:		$ -	$ -	$ -
State:		$ -	$ -	$ -
In kind: Because the project is overhead free, laboratory space, electricty, and other facilities/adminstrative costs (54% of direct costs excluding permanent equipment and graduate student tuition benefits) are provided in-kind.	*secured*	$ 109,000	$ -	$ 109,000
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

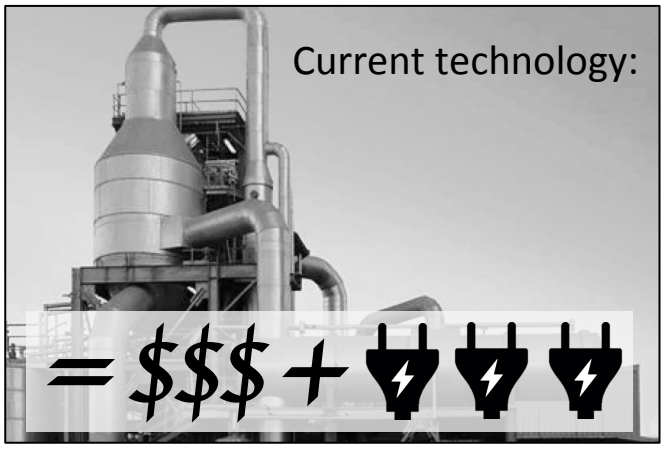
Centralized water softening and sulfate removal with **proven technology**: reverse osmosis (CCRO)

soft water to homes



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

concentrated saltwater (liquid waste)



Proposed technology:

= $ +