**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 MPCA1 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.1While 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**

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| **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** |

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| **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* |

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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.  **ENRTF BUDGET: $ 133,000** |

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| **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.