

**Environment and Natural Resources Trust Fund**

# 2021 Request for Proposal

## **General Information**

**Proposal ID:** 2021-282

**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

**Office Telephone:** (612) 219-3540

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## **Project Basic Information**

**Project 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.

**Funds Requested:** $262,000

**Proposed Project Completion:** 2024-06-30

**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 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 about the optimal physical design, ideal material properties for the hanging sheets, 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 the hanging sheets and horizontal trays**

**Activity Budget:** $129,000

**Activity 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. Modeling will include natural, forced, and mixed convection scenarios as well as both vertical sheets and horizontal trays.

**Activity Milestones:**

|  |  |
| --- | --- |
| **Description** | **Completion Date** |
| 1. Understand the fundamental equations governing evaporation of highly saline brines | 2021-12-31 |
| 2. Develop integrated model of enhanced evaporation from hanging sheet and horizontal tray | 2022-06-30 |
| 3. Validate model using in-lab prototype under simulated conditions | 2022-12-31 |

### **Activity 2: System optimization and piloting**

**Activity Budget:** $133,000

**Activity 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 Milestones:**

|  |  |
| --- | --- |
| **Description** | **Completion Date** |
| 1. Understanding of parametric relationships between system variables | 2023-06-30 |
| 2. Develop theory for an optimized system design | 2023-12-31 |
| 3. Pilot system tested under simulated conditions and techno-economic assessment for a MN WWTP prepared. | 2024-06-30 |

## **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 are actively pursuing 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 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 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:** 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. Ineli gible** | **% Bene fits** | **# FTE** | **Class ified 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 |  | $45,486 |
| Graduate Research Assistant |  | Analytical model extension, prototype design, fabrication, and testing. Includes UMN rate of 19.9% benefits plus tuition. |  |  | 43% | 1.5 |  | $156,021 |
| 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** | **$213,987** |
| **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. |  |  |  |  | $40,013 |
|  |  |  |  |  |  |  | **Sub Total** | **$40,013** |
| **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 (x3) | 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** | **$262,000** |

### **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 (54% of direct costs excluding permanent equipment and graduate student tuition benefits) are provided in-kind. | Secured | $109,000 |
|  |  |  | **Non State Sub Total** | **$109,000** |
|  |  |  | **Funds Total** | **$109,000** |

## **Attachments**

### **Required Attachments**

#### **Visual Component**

File: [47e038f8-07e.pdf](https://lccmrprojectmgmt.leg.mn/media/map/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](https://lccmrprojectmgmt.leg.mn/media/attachments/4071bb42-39f.pdf) |

## **Administrative Use**

**Does your project include restoration or acquisition of land rights?**
 No

**Does your project have patent, royalties, or revenue potential?**
 Yes,

 • Patent, Copyright, or Royalty Potential

**Does your project include research?**
 Yes

**Does the organization have a fiscal agent for this project?**
 Yes, Sponsored Projects Administration