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

Project Title: **ENRTF ID: 084-B**

Chloride-Free Home Water Treatment: Increasing Efficiency, Reducing Cost

Category: B. Water Resources

Sub-Category:

Total Project Budget: $ 265,000

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

Summary:

We will develop a new low-cost, high-efficiency pump that will enable a chloride-free solution to traditional household water softeners, thus eliminating the future cost of advanced treatment technology for WWTPs.

Name: Natasha Wright

Sponsoring Organization: U of MN

Job Title: Dr.

Department: Mechanical Engineering

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Minneapolis MN 55455

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Web Address:

Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

(1) house with a traditional water softener; pallet of salt represents the chloride required (2) house with a reverse osmosis-based softener that does not need chloride (3) the new pump

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

_____ Extent of Impact _____ Innovation _____ Scientific/Tech Basis _____ Urgency

_____ Capacity Readiness _____ Leverage _______ TOTAL _____%

PROJECT TITLE: CHLORIDE-FREE HOME WATER TREATMENT: INCREASING EFFICIENCY, REDUCING COST

I. PROJECT STATEMENT

Our goal is to develop a new **low-cost, high-efficiency pump** that will enable the use of point-of-entry (household) reverse osmosis-based water treatment and softening systems. If adopted, these systems will **eliminate the addition of chloride to our wastewater streams, thus eliminating the need for advanced treatment at WWTPs**, all while protecting residents and the environment from emerging contaminants.

Note: This study would complement the proposal *Reducing Chloride in Minnesota's Water from Water Softening* submitted by Dr. Sara Heger (UMN), which focuses of the evaluation of existing water softeners /conditioners.

Chloride levels in Minnesota's soils, lakes, wetlands, and groundwater is increasing, **harming aquatic life and the quality of our drinking water**. This chloride comes from multiple sources including the salt used for winter road maintenance, water softeners, industry, and agriculture. Recent LCCMR-funded work found that **household and commercial water softeners are the primary source of chloride** to wastewater treatment plants (WWTPs), contributing an estimated 65% to the total chloride discharge.* Because WWTPs are not equipped with the technology to remove chloride, it ends up back in MN waterways, accumulating each year. In **greater Minnesota**, household chloride generally flows to septic tanks, reaching groundwater through subsurface flow.

Traditional water softeners use ion exchange technology in which the ions causing hardness (calcium and magnesium) are exchanged for sodium. The system is recharged by adding more salt (in the form of sodium chloride) to the water softener. The dissolved chloride leaves the system as waste. While **no-salt water conditioners exist, these systems do not actually remove water hardness and are not well proven**.

An opportunity exists to **eliminate the use of traditional chloride-based water softeners utilizing proven technology**. **Reverse Osmosis (RO) is a proven technology** in which a pump is used to pressurize the feed water and force it through a semi-permeable membrane, removing water hardness without the use of chloride. RO has the added benefit of removing other contaminants (for example pharmaceuticals and heavy metals like lead and manganese), all while softening the water. **The MPCA estimates the upfront cost of installing a RO system at a WWTP would be $30-100 million which is not feasible for most towns**.** While household level point-of-entry RO systems are available, they are too expensive (>$5000) and waste too much water, discouraging widespread adoption. Recent developments, however, have led to a novel operating scheme called Closed Circuit Reverse Osmosis (CCRO). **CCRO has successfully decreased water waste to <10%, simultaneously reducing energy consumption and maintenance**, by recirculating the brine. However, this **requires pumps with precise flow control**. Little research has gone into the design of pumps capable of driving CCRO at the size-scale required for small treatment systems. **Existing pumps that could achieve the desired result are cost-prohibitive.**

Our goal of developing **a low-cost, high-efficiency, low-water waste, household RO system** will be achieved by modeling, optimizing, and prototyping a new progressive cavity pump (PCP) **designed out of injection moldable components**. PCPs have a number of benefits over other pumps including precise flow control without pulsations, and the ability to perform with high efficiency over a wide range of pressures; both requirements for CCRO. A PCP consists of an inner rod (called a *rotor*) that turns inside of an outer stationary housing (called a *stator*). Injection molded components would substantially reduce the capital cost of PCPs but would normally result in poor efficiency; manufacturing via injection molding leads to loose dimensional tolerances and causes a variable clearance between the rotor and the stator. To overcome this challenge, we will introduce a compliant (*flexible*, e.g. made of rubber instead of metal) stator. This will serve to counteract the variable clearance and allow some of the expensive mechanical components, such as bearings, to be removed, further reducing the capital cost and maintenance.

In order to develop such a pump, we must expand upon existing academic pump literature to model the variable clearances inherit with injection-molded components and couple that with models describing the flexible stator. We can then optimize, prototype, and test the pump in a CCRO system. **With these modifications, we aim for a chloride-free system, capable of removing hardness and other contaminants. Creating a system that is cost-competitive with current water softening technologies and eliminates the need for new installations of advanced treatment at WWTPs, we can save tax dollars and our waterways.**

*Overbo *et al.* Chloride Contributions from Water Softeners and Other Domestic, Commercial, Industrial, and Agricultural Sources to Minnesota Waters. Jan 2019.
**Minnesota Pollution Control Agency. Analyzing Alternatives for Sulfate Treatment in Municipal Wastewater. May 2018.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1 Title: *Model and Prototype: Incorporate the effects of variable clearances in theory and prototype*
Description: Current models for PCPs assume a constant clearance between the rotor and the stator. Because injection molding would result in non-uniform clearances, the existing literature will be extended to account for this. A rigid PCP will be prototyped and tested to understand the predictive capability of this model.
ENRTF BUDGET: $ 125,000

Outcome	Completion Date
1. Extension of existing models to include variable clearances between rotor and stator	*6/30/2021*
2. Experimentally validate the model using a rigid prototype	*12/30/2021*

Activity 2 Title: *Model and Prototype: Develop the theory and hardware necessary for a compliant stator pump*
Description: The model from Activity 1 will need to be combined with another model describing the flexible stator; together this will tell us how the fluid flow through the pump acts to structurally deform the stator, and how that in turn affects the fluid flow. Initial optimization for various pump parameters (for example, the diameter and length of the rotor) will allow us to analyze the tradeoffs in hydraulic and mechanical efficiency, quantity of material required, and manufacturing tolerances. We will work with various stakeholders in the residential water softening business to understand a representative operating point which will act as a case study for this optimization, and then prototype and test that pump.
ENRTF BUDGET: $ 140,000

Outcome	Completion Date
1. Couple the model from Activity 1 to an FEA model of the compliant stator	*6/30/2022*
2. Optimize the new coupled model for single case study	*12/30/2022*
3. Prototype and test compliant stator PCP	*6/30/2023*

III. PROJECT PARTNERS AND COLLABORATORS:

This proposal has the support of the Minnesota Pollution Control Agency, due to their continued search for water softening alternatives at the household level. We plan to communicate with them 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. We are also in conversation with Dr. Sara Heger (UMN) who has submitted a separate proposal under the title *Reducing Chloride in Minnesota's Water from Water Softening.* If both proposals are granted, the data from Heger's study of existing technology will be used to assess current limitations; incorporating those factors into our design.

IV. LONG-TERM IMPLEMENTATION AND FUNDING:

We are pursuing National-scale funding for this project in the next two years. We also hope to work with a team at the Carlson School of Management to determine realistic value propositions for the technology.

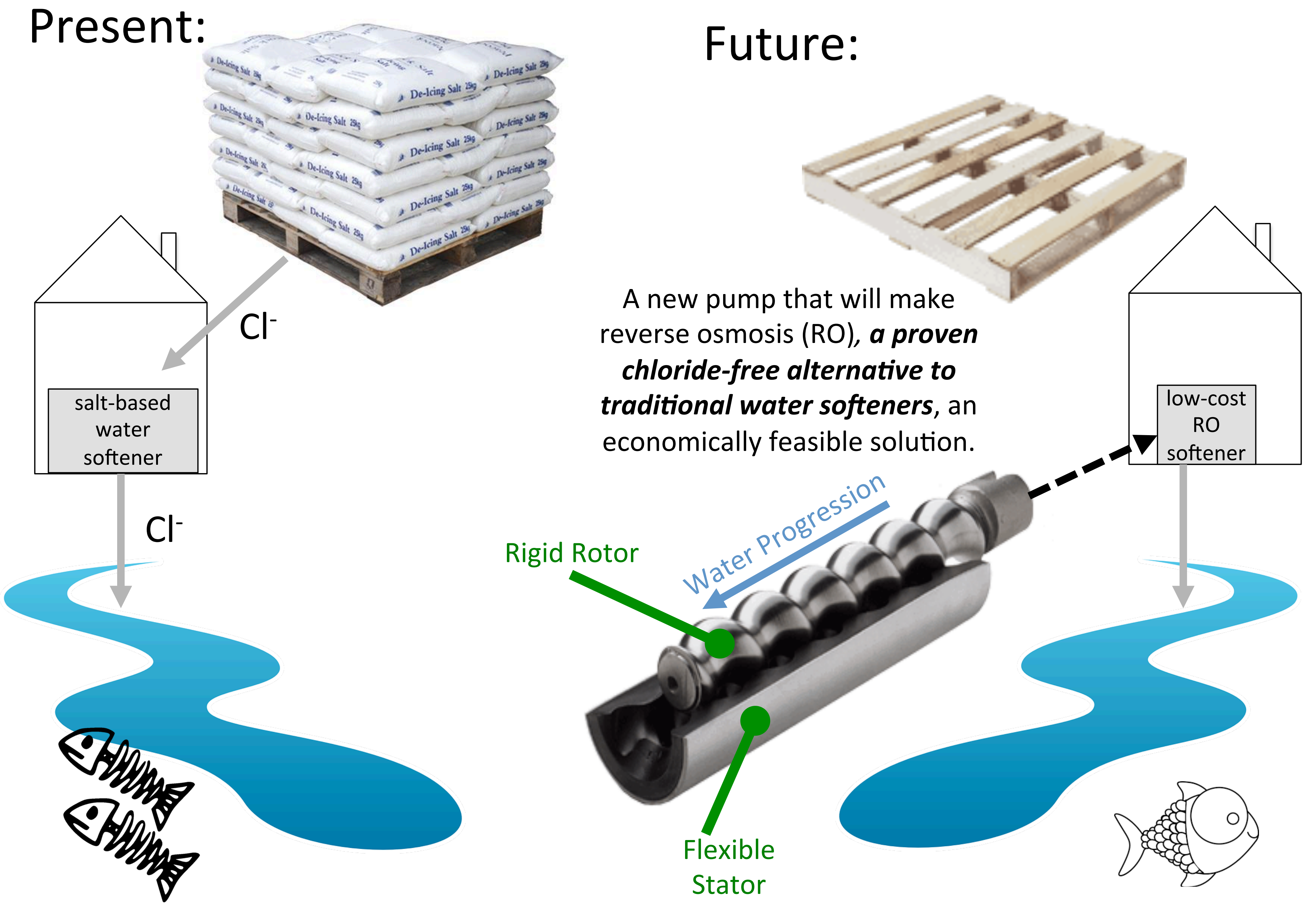
Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet

Legal Citation:	
Project Manager:	Natasha C. Wright
Project Title:	Chloride-free home water treatment: increasing efficiency, reducing
Organization:	University of Minnesota
Project Budget:	$ 265,000
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, pump 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 trial pumps. 10 hrs per week for one academic year. (100% salary) $12,500			
Professional/Technical/Service Contracts			
	$ -	$ -	$ -
Equipment/Tools/Supplies			
Prototyping Materials ($16,000 total), Supplies (consumable supplies, laboratory notebooks, FEA software license ($8,000 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 ($6,000 total)	$ 45,000	$ -	$ 45,000
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	$ 265,000	$ -	$ 265,000

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*	$ 117,000	$ -	$ 117,000
Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	**Amount legally obligated but not yet spent**	**Budget**	**Spent**	**Balance**
		$ -	$ -	$ -

Protecting Minnesota Waterways and Aquatic Life



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.