Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2018 Work Plan

Date of Report: February 21, 2018

Date of Next Status Update Report: December 31, 2018

Date of Work Plan Approval:

Project Completion Date: June 30, 2021

Does this submission include an amendment request? No

PROJECT TITLE: Develop Small and Inexpensive Purification System for Community Drinking Water

Project Manager: Tianhong Cui

Organization: University of Minnesota

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Web Address:

Location: Minneapolis, MN

Total Project Budget: $425,000

Amount Spent: $0

Balance: $425,000

Legal Citation:

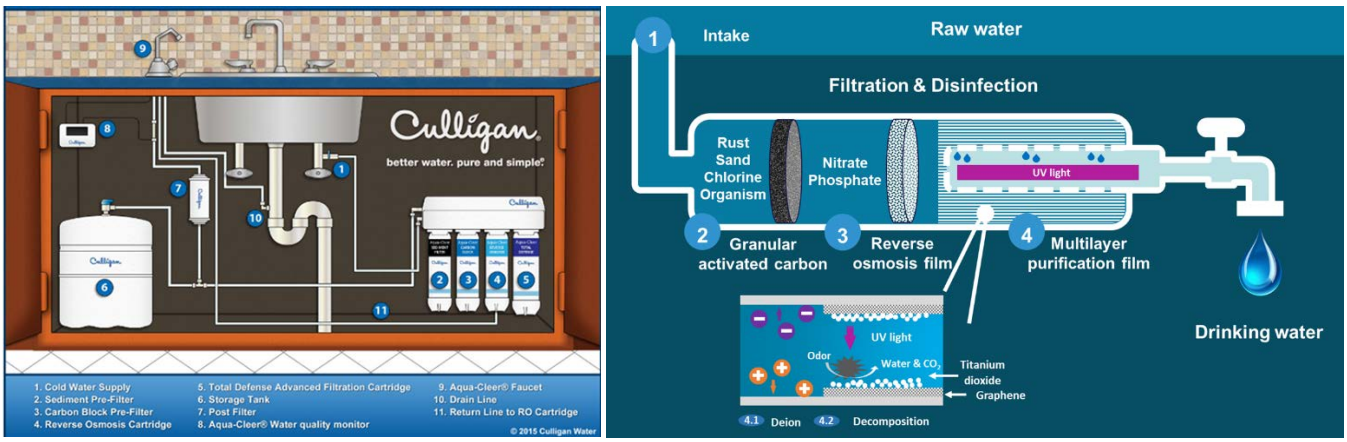
Appropriation Language:

I. PROJECT TITLE: Develop Small and Inexpensive Purification System for Community Drinking Water

II. PROJECT STATEMENT:

The objective of this project is to develop a small cheap purification system for cleaner community drinking water, as show in Figure 1. Current drinking water purification systems for community water are usually large, expensive, and difficult to operate. The proposed community water purification system is very small and low-cost, but more efficient to remove organic and inorganic contaminants. The water purification system is composed of porous activated carbon, reverse osmosis film, columnar UV light source, and a roll of multilayer purification film. The multilayer purification film is made of an electrically conductive film, by self-assembly of graphene and titanium oxide nanoparticles on the surface of plastic. When water purification is in progress, a small biased potential is applied to the conductive film, and the UV light is turned on. Water flowing into the system will be pre-treated by the activated porous carbon and reserve osmosis film, and some microbes, organic matters, small particles, nitrate and phosphate are removed. Next, the pre-treated water enters the multilayer purification film, where microbes can be further deactivated by the UV light and the porous structures. Water soluble ions, such as lead, cadium, etc. can be reduced electrochemically or absorbed by the electric field. Titanium oxide, as a photosensitive material, will have photochemical behavior under UV illumination, to detoxify some organic matters. Through the above process, much cleaner drinking water can be obtained very efficiently. This project is intended to develop small, cheap, but efficient purification system for cleaner community drinking water.

In the next phase of the research, we will closely work with state agencies, water pollutant researchers, and industry to develop an implementation plan for pollutants reduction of drinking water in heavy industrial or agricultural regions in Minnesota.



Current Technology **New Technology Proposed**

Figure 1. A comparison of drinking water purification system between the current and proposed technologies.

III. OVERALL PROJECT STATUS UPDATES:

First Update December 31, 2018:

Second Update June 30, 2019:

Third Update December 31, 2019:

Fourth Update June 30, 2020:

Fifth Update December 31, 2020:

Final Update June 30, 2021

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Development of small cheap community water purification systems

Description: The objective of this activity is to develop water purification systems using plastic, graphene and titanium oxide nanoparticles. The system is very small, cheap, and reliable to remove organic and inorganic contaminants in Minnesota community waters. The system will reduce the water contaminants to meet the EPA and Minnesota standards, while the cost is one tenth and the room is one fifth of the traditional systems at most.

We propose a new drinking water purification system to be an alternative to conventional ones. We will develop new technologies enabling easy installation of smaller drinking water purification systems with very low cost and high efficiency. When water purification is in progress, a small biased potential is applied to the conductive plastic film, and the UV light is turned on. Water flowing into the system will be firstly pre-treated by the activated porous carbon and the reserve osmosis film, and some microbes, organic matters, small particles, nitrate and phosphate are removed. We will use a reverse osmosis film to remove nitrate and phosphate. Next, the pretreated water enters the multilayer purification film, where microbes can be further deactivated by the UV light and the porous structures. Water soluble ions, such as lead, cadium, or nitrates, can be reduced electrochemically or absorbed by the electric field. Titanium oxide, as a photosensitive material, will have photochemical behavior under UV illumination, to detoxify some organic matters. Due to the outstanding material properties of graphene/ Titanium oxide and the advanced micromanufacturing techniques available at the University of Minnesota, we propose to make drinking water systems, which are small, cheap, and highly efficient. To meet the goal of the MPCA, this project will make significant impacts on drinking water purification in Minnesota waters.

Specific tasks will be:

1. **Materials and hardwares development**

Materials and hardwares are developed and demonstrated, which is expected to:
(1) Layer-by-layer self-assembled graphene/titanium dioxide nanocomposites.
(2) Hardwares for water purification systems.

(3) Initial testing results of water purification to remove organic and inorganic particles.

2. Development of drinking water purification systems

Drinking water purification systems are developed and demonstrated, which is expected to:
(1) Purification efficiency of small drinking water purification systems will be tested.
(2) Improved systems with optimized design, fabrication, and testing.
(3) Drinking water systems testing in Minnesota.
(4) Comprehensive assessment of the techniques.

Summary Budget Information for Activity 1:

ENRTF Budget: $ 275,569
Amount Spent: $ 0
Balance: $ 275,569

Outcomes	Completion Date
1. Layer-by-layer self-assembly of graphene/titanium dioxide nanocomposites; hardware will be developed for water purification systems; Initial testing results of water purification to remove organic and inorganic particles	*6/30/2019*
2. Purification efficiency on small systems will be tested in comparison with conventional results in lab; Improved systems with optimized design, fabrication, and testing; Systems testing of water in Minnesota	*6/30/2020*
3. Comprehensive assessment of the techniques will be completed	*6/30/2020*

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ACTIVITY 2: Development of standard size water purification systems and field testing

Description: A prototype standard size purification system to be assembled with the community water supply will be designed and constructed. We will develop prototype standard size purification system, as shown in Figure 2. The water purification system is composed of porous activated carbon, reverse osmosis film, columnar UV light source, and a roll of multilayer purification film.

Test sites will be set up to demonstrate the feasibility of the systems. Field testing will include picking up community sites and testing the efficiency of the systems in the field. Upon completion of the project, we will demonstrate the purification systems to the stakeholders, LCCMR committee members and officials.

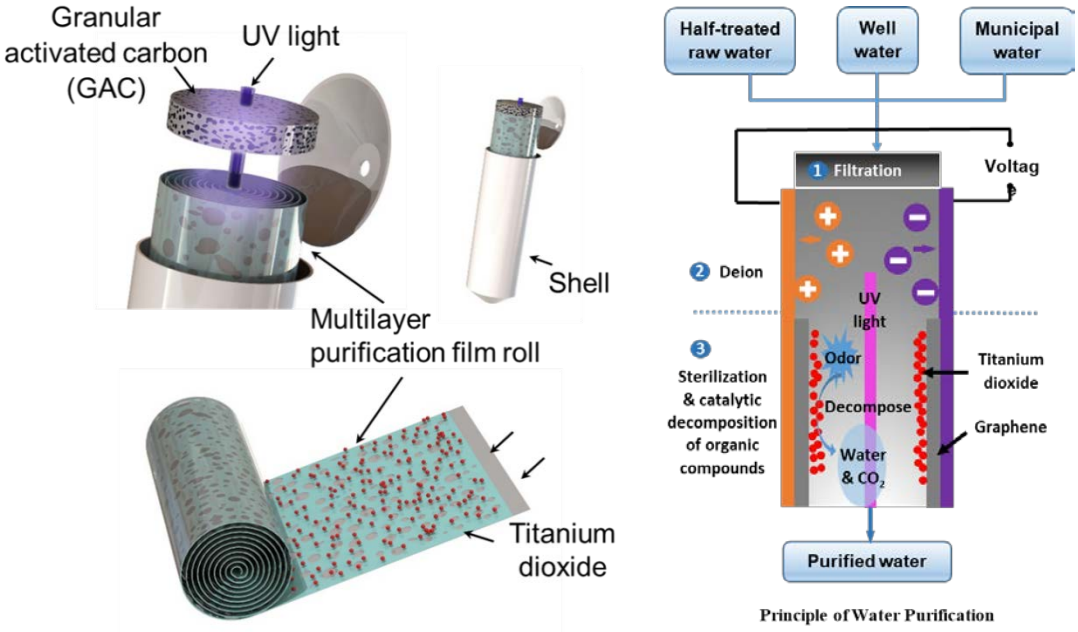

Figure 2. New Design of Drinking Water Purification System.

Specific tasks will be:

Development of standard size water purification systems and field testing
Standard size water purification systems and field testing are done, which is expected to:
(1) Designed and developed drinking water purification systems in standard size.
(2) Test sites with residential community water sites.
(3) Field testing at field sites, and tested purification efficiency.

Summary Budget Information for Activity 2:

ENRTF Budget: $ 149,431
Amount Spent: $ 0
Balance: $ 149,431

Outcomes	Completion Date
1. Standard size systems will be designed and developed	*12/31/2020*
2. One or two test sites with residential community water sites will be set up	*3/31/2021*
3. Field testing will be performed with filed sites, and purification efficiency will be tested	*6/30/2021*

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V. DISSEMINATION:

Description:

The findings will be disseminated through:

(1) On site demonstration as described in the activities
(2) Public seminars
(3) Progress update on www.me.umn.edu
(4) Presentations at national and international technical conferences
(5) Communications with interested entrepreneurs
(6) Peer reviewed papers
(7) Collaboration with MPCA

The technologies, if demonstrated successfully, may be implemented to community and home drinking water purification in the State of Minnesota and beyond. Any intellectual properties and related revenues as a result of the program will be shared between UMN and LCCMR.

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Third Update December 31, 2019:

Fourth Update June 30, 2020:

Fifth Update December 31, 2020:

Final Update June 30, 2021

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview: See attached budget spreadsheet

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than $5,000: N/A

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 1.11 FTE

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: 0

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
State			
The university overhead unpaid	$205,087	$0	Develop a Small and Inexpensive Community Drinking Water Purification System
TOTAL OTHER FUNDS:	**$205,087**	**$0**	

VII. PROJECT STRATEGY:

A. Project Partners:

Tianhong Cui, Distinguished McKnight University Professor at the University of Minnesota, will serve as PI and project manager. Professor Cui is a leading expert on advanced manufacturing and micro devices. He will be responsible for overseeing the project, all reports, and deliverables. A research assistant and a post-doc will develop the systems, in-lab test sites with dirty water, and set-ups for field testing of the proposed purification systems for community drinking water.

B. Project Impact and Long-term Strategy:

Minnesota Pollution Control Agency (MPCA) works together with other agencies and advocacy groups in developing strategy to keep clean drinking water, reducing their impacts on human health and the environment. Water is one of the most valuable natural resources in the world. In everyday life, people use water in many ways, such as drinking, cooking, washing, etc. It is very important to ensure the supplied water is clean, especially the drinking water for daily life. Although tap water meeting federal and Minnesota state standards is usually safe to drink, people are still confronted with an increasing threat to contaminated water. It has been reported that over 200,000 violations to federal drinking water standards each year, among which more than 20% are due to poor water treatment facilities. Therefore, a small cheap but efficient community water purification system is very important to ensure a healthy drinking water supply, especially for those who are vulnerable to waterborne diseases. Commercially available community water treatment systems utilize various water cleaning technologies with several components, including activated carbon filter unit, ion exchange unit, reverse osmosis unit, and distillation unit. The purification system consists of a sediment pre-filter, a carbon block pre-filter, a reverse osmosis cartridge, and a total defense advanced filtration cartridge. Through the above units, contaminants, such as heavy metal ions, microbes, dissolved solids, organic pollutants can be removed from the water, so that clean drinking water can be obtained. The commercial systems provide the users with purified drinking water, but the price is relatively high, ranging from hundreds to thousands dollars. In addition, due to the large volume of the purification systems, it occupies much room. The proposed new purification system will provide a solution to current ineffective and expensive community water treatment systems, and thus ensure people's cleaner drinking water in Minnesota.

The knowledge learned throughout the project will provide a solid foundation for further research and development that would lead to eventual implementation of the new technique practically enabling broader treatment of Minnesota's water. This will provide a solution to current ineffective water treatment, ultimately help implement the MPCA's clean water strategy, and thus ensure people's safety in Minnesota.

In addition, we will plan to file patents on the proposed community drinking water purification system for commercialization in the future. We can also use the new technology for treatment of natural water, waste water, etc. As a result, the innovative technology can benefit the local residents and society by purifying the waters in Minnesota.

C. Funding History:

Funding Source and Use of Funds	Funding Timeframe	$ Amount
Mocon Inc., Graphene gas sensors	Nov. 2014 - July 2016	$173,199
Alexandria Extrusion Inc., Microstructures for Heat Transfer	Nov. 2011 - Dec. 2015	$165,516
DARPA, MEMS-Based Active Heat Sink Technology	Jan. 2009 - Sept. 2013	$2,579,025
MN Partnership, Nano-Sensors	Jan. 2010 – Dec. 2012	$637,500

VIII. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS:

IX. VISUAL COMPONENT or MAP(S):

See the attachment.

X. RESEARCH ADDENDUM:

XI. REPORTING REQUIREMENTS:

- The project is for 3 years, will begin on 07/01/18, and end on 06/30/21.
- Periodic project status update reports will be submitted [06/30] and [12/31] of each year.
- A final report and associated products will be submitted between June 30 and August 15, 2021.

Attachment A:
Environment and Natural Resources Trust Fund
M.L. 2018 Budget Spreadsheet

Project Title: Develop Small and Inexpensive Purification System for Community Drinking Water
Legal Citation:
Project Manager: Dr. Tianhong Cui
Organization: Univeristy of Minnesota
College/Department/Division: Department of Mechanical Engineering
M.L. 2018 ENRTF Appropriation: $425,000
Project Length and Completion Date: 3 years/ June 30, 2021
Date of Report: February 21, 2018

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits) - overall	$304,131	$0	$304,131
Dr. Tianhong Cui, PI, 1 month summer salary (11% FTE) & 33.5% fringe for 3 years (Total estimated amount $69,512)			
Post-Doc or visiting scholar, 6 months (50% FTE) plus 21.4% fringe for 3 yearsTotal estimated amount $90,056)			
Graduate Research Assistant, 50% FTE (fall & spring semesters include 16.9% fringe plus $18.94/hour tuition, summer 15% fringe only) for 3 years (Total estimated amount $144,563)			
Professional/Technical/Service Contracts			
Equipment/Tools/Supplies			
Lab Materials & Supplies: fabrication materials & supplies including polymer substrates ($10,000), nanomaterials and chemicals ($15,000), roll-to-roll manufacturing set-up items ($14,619), bottles, gloves, other electronics for testing, etc. ($10000)(Total estimated amount $49,619)	$49,619	$0	$49,619
Travel expenses in Minnesota			
Travel- Cui Domestic travels: Mileage, lodging, and meals for travel to and between the driking water testing sites and the university based on the university compensation policy	$8,250	$0	$8,250
Other			
Sceintific Services: User fees at Minnesota Nano Center and Characterization Facility at the University of Minnesota. The cost is estimated at about $1,000 per month for the Post-Doc, and $750 per month for the research assistant for 3 years. Actual charges based on equipmnet rate and time used will be charged. (See note below)	$63,000	$0	$63,000
COLUMN TOTAL	$425,000	$0	$425,000

Note: Scientific Services: User fees at Minnesota Nano Center and Characterization Facility at the University of Minnesota. The cost is about $1,000 per month for the Post-Doc, and $750 per month for the research assistant for 3 years. This is an estimate cost of equipment usage fees at the two central facilities, and the real charges are based on equipment usage time that the two researchers will actually run the machines for fabrication of the testing purification systems and characterization of materials for the purification systems.

The post-Doc and the research assistant need use the following machines at the two central facilities. The fabrication machines include Atomic Layer Deposition Machine (ALD Savannah 200, Fiji PEALD), 2D Material Growth Equipment (Graphene furnace, TMD furnace), E-Beam Evaporation (CHA, Temescal and Varian), Sputter (AJA I, AJA II and PE2400 DC system), Nanoimprinter (Nanonex), Laser Writer (Heidelberg DWL 200), Mask Aligner (MA6), etc. The characterization equipment includes Ion Beam Analysis, SEM (Jeol SEM, Amray SEM), X-Ray Diffraction, X-ray photoelectron spectroscopy (XPS), etc. The actual cost is based on the real time used on each machine with academic rates.