Environment and Natural Resources Trust Fund
2018 Request for Proposals (RFP)

Project Title: **ENRTF ID:** **163-E**

A Solar-Powered Electrochemical System for Sulfide Removal

Category: E. Air Quality, Climate Change, and Renewable Energy

Total Project Budget: $ 435,000

Proposed Project Time Period for the Funding Requested: 3 years, July 2018 to June 2021

Summary:

This project will develop a solar-powered electrochemical system to be applied to remove major odorous sulfide compounds in sewage and to remove sulfur from acid mine drainage.

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Sponsoring Organization: U of MN

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

A solar-powered electrochemical system for sulfide removal

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

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

_____ Capacity Readiness _____ Leverage _______ TOTAL ______%

PROJECT TITLE: A Solar-Powered Electrochemical System for Sulfide Removal

I. PROJECT STATEMENT

This project will develop a solar-powered electrochemical sulfide removal system and it will be applied to remove major odorous compounds in sewage collection and treatment systems, as well as to remove sulfur from acid mine drainage.

Sulfur is an essential element in living organisms and soil. The most commonly seen sulfur compound is sulfates, metal salts with a combination of sulfur and oxygen. It is the main chemical in the acid mine drainage in the sulfide mining sites and it can contaminate lakes, rivers, and groundwater, harm human health, fish, wildlife, and damage entire ecosystems if not properly treated. Sulfate will be reduced by the sulfur reducing bacteria to the inorganic form, sulfide, which is the source of rotten egg odor for a lot of well water in greater Minnesota. The presence of sulfide in sewer and sewage treatment systems is also a common issue in both decentralized septic systems and wastewater treatment plants. Sulfide causes concrete corrosion, cracking, and eventually infrastructure failure. The corrosion thus costs $14 billion annually in United States alone. The protonated form of sulfide, hydrogen sulfide, is an important source of sewer odors, and is hazardous to exposed humans.

The environmental and economic concerns have long stimulated research on mitigation methods for sulfide control, including decreasing sulfur in source water, increasing water oxidation-reduction potential to inhibit biogenic sulfide production, and adding oxidizers or precipitators to convert it to other more stable sulfur chemicals. Methods to reduce sulfide from source are still under research; and the other methods are chemical and energy-intensive and potentially bring in more chemical contaminants to water. Electrolytic process with intermediates generation, e.g. oxygen gas by electrochemical water oxidation, can be applied for sulfide mitigation, but it consumes relatively more electrical power and is not selective to sulfide oxidation thus decreasing coulombic efficiency and increasing energy cost.

The research team completed an early LCCMR project (133-E for 2014-2017) of renovating septic tanks for nutrient removal. A substantial hydrogen sulfide removal in the septic tank with the electrochemical system was found in that research. In this project, we want to further study this system in great details and develop applications in different fields. We want to look for cheap materials to decrease the odor compounds in sewage treatment, i.e., eliminating major odorous compounds at a lower cost; and explore an economically feasible method to address the acid mine drainage issue.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Develop an electrochemical system in bench-scale to remove sulfide **Budget: $147,000**

The objective of this activity is to seek less-expensive electrode materials and study the operational conditions for sulfide removal. Based on our preliminary research, we want to focus our study on low carbon steel or stainless steel AISI 430 as two types of sacrificing anode materials. The search will also be extended to other active and non-active materials, for instance stainless steel AISI 304, rusted stainless steel AISI 304, graphite, SnO_2, PbO_2, TiO_2 coated on either Ti or stainless steel 304 plates. The operation conditions will also be studied, including voltage, electrode surface area, etc.

Outcome	**Completion Date**
1. Establish analysis methods for gas and high-performance liquid chromatography	*09/31/2018*
2. Optimize both active and non-active anode materials for sulfide removal	*05/31/2019*
3. Estimate the cost of material and operation of each condition	*06/30/2019*

Activity 2: Testing the system in sewer and acid mine drainage **Budget: $141,000**

We will build a pilot-scale (5 gallons – 100 gallons) of electrochemical reactor using the selected electrode materials. The reactor will be connected to municipal wastewater for the sulfide and odor removal and the system will be evaluated for six months. The gas emission and liquid will be periodically analyzed for typical odorous compounds including hydrogen sulfide, methyl mercaptan ammonia, volatile fatty acids, phenol and indole. Meanwhile, concrete coupon will be put in pipes for corrosion detection. The selected electrode material will also be assessed for sulfur removal in drainage from acid mine tailings. The drainage will be subjected to microbial reduction in 20-L packed bed bioreactor in order to convert all sulfur compounds to sulfide. Then, sulfide will be removed by the electrochemical system.

Outcome	Completion Date
1. Fabricate pilot-scale sulfide removal system	*09/30/2019*
2. Operate the system with sewer municipal wastewater	*03/31/2020*
3. Operate the system with acid mine drainage	*06/31/2020*

Activity 3: Incorporating a solar panel for powering the system **Budget: $147,000**

The objective of this activity is to test the technical and economic feasibility of replacing the power requirement with sustainable solar energy so that it can be self-sustained in the field. Photovoltaic solar panel, with a designated surface area calculated from the power requirements in the previous two activities, will be purchased and installed to the electrochemical system. The solar-powered electrochemical sulfide control system will be deployed to the fields, including a sewer pipe and an acid mine drainage site. The sulfide and odor removal performance will be assessed by chemical analysis, odor activity value and an odor panel for final confirmation. An economic analysis of applying the proposed technical solution will be conducted to address the feasibility of its commercial implementation.

Outcome	Completion Date
1. Incorporate a photovoltaic solar-panel	*10/31/2020*
2. Test the solar-powered treatment systems in the fields	*04/30/2021*
3. Conduct a techno-economic assessment of the technology	*06/30/2021*

III. PROJECT STRATEGY

A. Project Team/Partners: The research team sponsored by the project will be consisted of Dr. Bo Hu, Associated Professor at UMN; a Post-Doc researcher, and a PhD graduate student. Dr. Hu will design and coordinate the research; the Post-Doc researcher will be hired to assist in design and experimentation; and the graduate student will assist in data collection and dissertation. We have built a collaborative partnership with Mr. Mike Rieth P.E., Principal Research Engineer, Process Engineering and R&D, MCES Metro Plant on the LCCMR project M.L. 2014, Chp. 226, Sec. 2, Subd. 08g, “Next Generation Large-Scale Septic Tank Systems” to set up a pilot-scale demonstration reactor for phosphorus removal at Saint Paul Municipal Wastewater treatment plant. We will continue engaging and partnering with them on this project for sulfide and odor removal. We will also identify an industrial collaborator at a sulfide mining site for the acid mine drainage water treatment.

B. Project Impact and Long-Term Strategy: The electrochemical system can potentially be materialized and commercialized to address sulfide issues in both WWTP in the cities and acid mine drainage in greater Minnesota. The technology can find wider applications than what is proposed here, e.g., in waste storage circumstances like manure storage, sugar beet waste storage, and meat/rendering processing waste storage. Besides the activities in this project, we will also explore partnerships and collaborations with those industries for potential further developments in addressing sulfide issues in their processes.

C. Timeline Requirements: We plan to finish the proposed activities in three years.

2018 Detailed Project Budget

Project Title: A solar-powered electrochemical system for sulfide removal

IV. TOTAL ENRTF REQUEST BUDGET *3* years

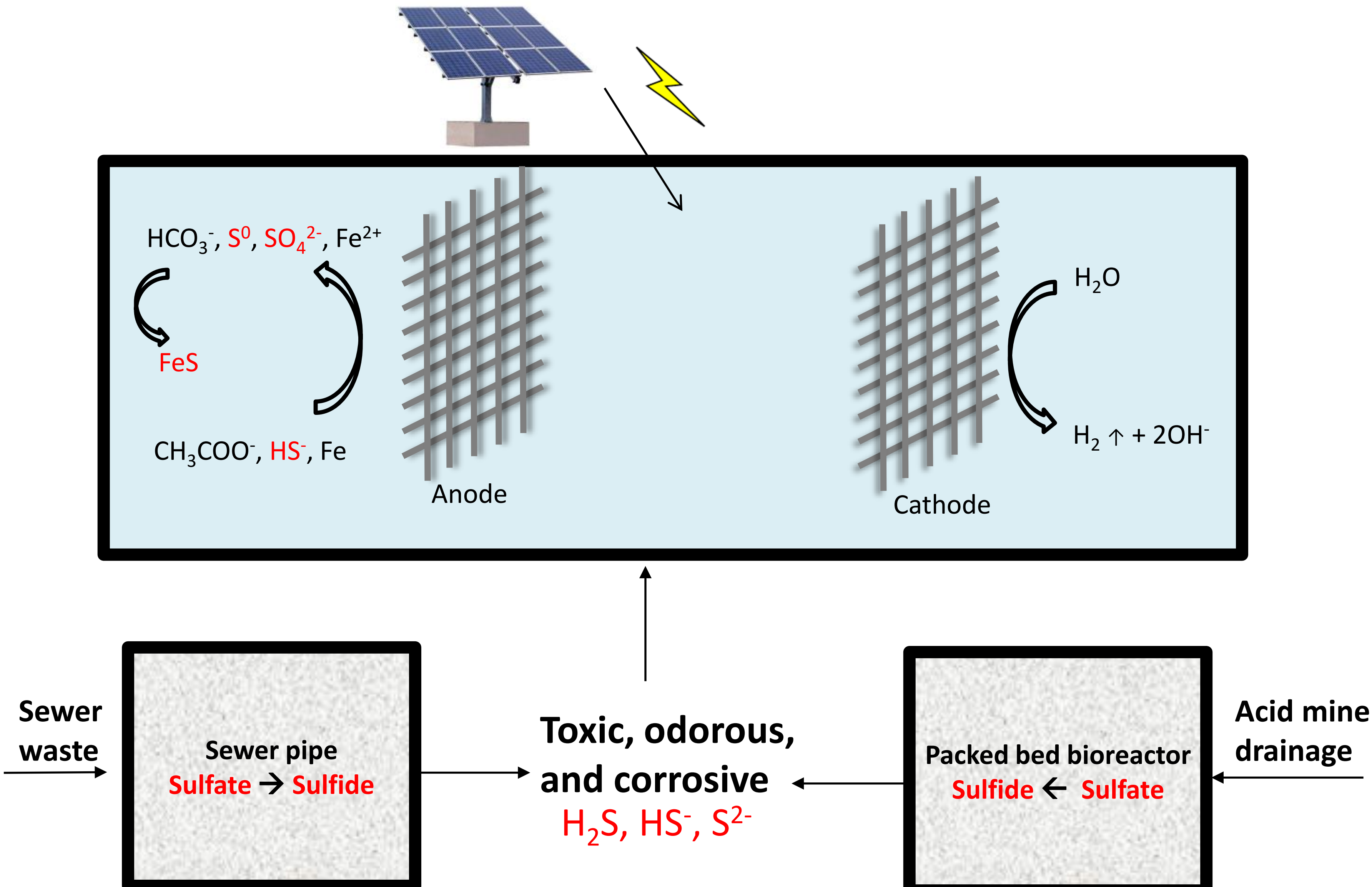
BUDGET ITEM	AMOUNT
Personnel:	
Bo Hu, Project Manager (68% Salary, 32% Benefits), 8.3% FTE per year for three years	$ 42,000
Research Associate (68% Salary, 32% Benefits), 100% FTE for 3 years	$ 209,000
Graduate student, Research assistant, 50% FTE	$ 137,000
Professional/Technical/Service Contracts	
Professional analysis service for water and solid samples at other UMN analytical labs	$ 6,000
Equipment/Tools/Supplies:	
Supplies for the lab experiments to purchase necessary chemicals, test kits, electrodes, and other materials	$ 25,000
Acquisition (Fee Title or Permanent Easements): N/A	$ -
Travel:	$ -
In-state travel (Mileage, lodging, and meals) to the site for collecting water samples	$ 3,000
Additional Budget Items	$ -
We will build a pilot scale device that can be used to demonstrate the sulfide removal technology at Municipal Wastewater Treatment in Saint Paul and at one mining site in Northern MN	$ 10,000
Publication costs for two/three papers, page charges	$ 3,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 435,000

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:	$ -	
Other State $ To Be Applied To Project During Project Period:	$ -	
In-kind Services To Be Applied To Project During Project Period	$ 204,000	*UM F&A*
Past and Current ENRTF Appropriation:		
M.L. 2014, Chp. 226, Sec. 2, Subd. 08g, “Next Generation Large-Scale Septic Tank Systems”	$ 218,000	ends in 6/30/2017
Other Funding History:	$ -	

Project title: A solar-powered electrochemical system for sulfide removal

Summary: *A solar-powered electrochemical system will be developed to economically remove sulfide from sewage treatment and acid mine drainage.*



Project Manager Qualifications

The research team will include Dr. Bo Hu and his Post-Doc researcher and PhD graduate student from the Department of Bioproducts and Biosystems Engineering.

Dr. Bo Hu is a junior Associate Professor at Department of Bioproducts and Biosystems Engineering, University of Minnesota. With more than 10 years of active research experience specifically in biomass utilization, fermentative conversion, and waste management, he is leading projects to remove phosphorus from manure and from wastewater in the septic tank systems, projects to reveal the myth of recent swine manure foaming in Midwestern states, projects on synthetic ecology in lichen biofilm formation by co-culturing mixotrophic microalgae and filamentous fungi. He has finished projects to develop a co-digestion system in Jer-Lindy dairy farm in Minnesota and a modified anaerobic digestion system for biohydrogen production. Dr. Hu's team at UMN has set up several standard procedures such as 16s rDNA based microbial analysis by using high-throughout pyrosequencing methods to study the microbial species in the waste treatment processes, ITS sequences to identify fungal species. His team is also developing several conversion platforms, such as lichen biofilm co-cultivation of fungi and microalgae, pelletized fungal fermentation, and solid and hemi-SolidSF of filamentous fungi, to produce bioprducts and biofuel from agricultural waste and residue, and to remove nutrients and pollutant from contaminated water. As the PI of the project, Dr. Hu will design and coordinate the research; the Post-Doc researcher will assist in design and experimentation; and the graduate student will assist in data collection and dissertation.

Dr. Hu's laboratory has all the necessary equipment and facilities for this project, including: Bio-Rod MJ Mini 48-Well Personal Thermal Cycler, Bio-Rod electrophoresis, New Brunswick refrigerated incubation shaker INNOVA 42R, New Brunswick shaker Excella E-24, Beckman Allegra X-15R Refrigerated Centrifuge, VWR refrigerated water heater circulator, Bioreactor/fermentor, Agilent 7820 A GC-FID-TCD [gas-chromatography analysis–flame-ionization detector–thermal conductivity detector] , Agilent Micro-GC, Agilent 1260 HPLC (Diode Array detector, Refractive Index Detector and autosampler), and Dionex ICS 2100/ ICS 1100 bundle ThermoFisher Scientific. Other basic equipment within the lab includes Biosafety cabinet, Autoclave, -20 freezer and 4 degree refrigerator, balances, pH meter, etc.. The lab is also equipped with two incubation rooms with full range of temperature control, a walk-in refrigeration room and a walk-in cold room.

As a participating faculty of Biotechnology Institute of UMN, Dr. Hu has the access to the Biotechnology Resource Center, which is a 4000 square-foot laboratory/pilot plant facility with state-of-the-art equipment for research and development in fermentation, animal cell culture technology, molecular biology, protein expression, and separation of a wide range of biological molecules. The facility has a wide range of bench-scale to pilot-scale fermenters available, ranging in size from 6 L to 300 L. The university also has the following facilities that can be accessed with payment: Center for Mass Spectrometry and Proteomics. This facility is house in the basement of the Gortner / Snyder complex and provides support, equipment and expertise for analyzing complex protein mixtures. This facility has several full-time staff trained to run and troubleshoot experiments. It is an NSF funded core facility (NSF Grant 9871237, Dr. Gary Nelsestuen, PI) and is home to the University of Minnesota Mass Spectrometry and Proteomics Initiative that can provide matching funds for in house proteomic projects.

Organization Description

As the core department of UMN to tackle Agricultural engineering and environmental engineering issues, Bioproducts and Biosystems Engineering Department has very dynamic research activities and numerous excellent scientific researchers have received grant supports from LCCMR program. UMN Sponsored Projects Administration (SPA) will be the entity authorized by the Board of Regents to manage the project agreements with LCCMR program.