Environment and Natural Resources Trust Fund
2019 Request for Proposals (RFP)

Project Title: **ENRTF ID:** 118-BH

Electrochemical Process to Protect Sewer System from Sulfide

Category: H. Proposals seeking $200,000 or less in funding

Sub-Category: B. Water Resources

Total Project Budget: $ 199,924

Proposed Project Time Period for the Funding Requested: June 30, 2022 (3 yrs)

Summary:

We want to develop an electrochemical system to protect sewage wastewater transportation and handling facilities and septic tanks from sulfide corrosion and reduce odor emissions

Name: Bo Hu

Sponsoring Organization: U of MN

Title: Associate Professor

Department: Bioproducts and Biosystems Engineering

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Web Address

Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

This visual contains illustrations on what we propose to work on the project

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

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

_____ Capacity Readiness _____ Leverage _______ TOTAL ______%

____ If under $200,000, waive presentation?

PROJECT TITLE: Electrochemical process to protect sewer systems from sulfide

I. PROJECT STATEMENT

The presence of sulfide species in sewage wastewater transport and handling facilities and septic systems causes infrastructure corrosion and odor emissions. Hydrogen sulfide is generated by sulfate-reducing bacteria when organic matter in sewage is degraded under the naturally anaerobic conditions. When sewage is gravitationally delivered to receiving wells in wastewater treatment plants, a lift station that transport wastewater to treatment facilities disturbs liquid phase and accelerates hydrogen sulfide emission as a source of sewer odor. In concrete sewers, hydrogen sulfide can gradually cause concrete corrosion, deterioration, cracking, and eventually infrastructure failure. Sulfide-induced corrosion alone costs $14 billion annually in United States, while the resulting cost induced by emissions is not yet included. The huge monetary loss has long stimulated research on mitigation methods, including decreasing sulfur in source water, increasing water oxidation-reduction potential to inhibit biogenic sulfide production, and adding oxidizers or precipitators to convert soluble sulfide to more oxidized products or insoluble precipitates. Source reduction is still at its preliminary discussion stage, and the other two categories of methods are chemical and energy-intensive and potentially bring in more chemical contaminants to wastewater. Alternatively, electrochemical/microbial electrochemical processes are recently under development in order to reduce sulfide mitigating cost, where sulfide is oxidized to elemental sulfur or sulfate with no or little chemical and energy inputs. Specifically, microbial electrochemical oxidation (MEO) is a unique concept that it directly utilizes electrode and electrode-biofilm interface to oxidize sulfide for a better coulombic and energy efficiency.

The goal of the study is to develop an effective MEO process to prevent sewer corrosion and odor emission. We have already done preliminary study on several types of waste streams, including synthetic sulfide-containing media, sewage, sugar beet processing wastewater, deep-pit swine manure, and surface-scrubbed swine manure. Our preliminary results clearly demonstrated its effectiveness for sulfide removal. In this study, we propose to apply this technology to sewers or wastewater receiving wells to decrease corrosion and odor emission. This study will minimize the sludge accumulation during treatment by optimizing electrode materials and operating conditions. We will monitor the long-term performance of simulated sewers and receiving wells assisted with MEO process in terms of hydrogen sulfide content in headspace air, solids accumulation, and corrosion on sample concrete coupons.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Abiotic sulfide oxidation reactions with different electrodes materials **Budget: $97,959**

We will study potential electrode materials for sulfide oxidation, including different types of stainless steels, graphite carbon cloth, mixed metal oxides, and sacrificing electrodes made of iron. The electrode with best oxidation catalytic effects will be chosen for batch abiotic experiments for sulfide oxidation. The batch abiotic experiment will be conducted at a range of applied direct voltage between 0.5 V and 1.5 V with 0.1 V increment with each voltage for 24 hours. The medium will be analyzed for sulfur species via ion chromatography and ion selective electrode, and headspace gas for hydrogen sulfide via gas chromatography. The dry weight of electrode materials will be compared before and after the treatment, and the produced solids or sludge will be fractionated and compared among materials/voltages. The above experiments will yield data for selection of an electrode material and a voltage for the oxidation products to be either elemental sulfur or sulfate.

Outcome	Completion Date
1. Fabricate lab-scale reactors	*09/30/2019*
2. Optimize both active and non-active anode materials for sulfide removal	*12/31/2020*

Activity 2: ***Long-term operation in simulated sewer pipes and receiving wells*** **Budget: $67,636**

The performance of sulfide removal by treatment installation in sewers or receiving wells will be assessed. Suitable sizes of simulated sewers and receiving wells will be prepared for lab-scale test. The selected electrode material will be fabricated to electrodes of desired shape configuration and installed in simulated concrete sewers or receiving well, with control group without electrochemical units. For both tests in simulated sewers and receiving wells, the systems will be fed at a predetermined flow rate with simulated sewage prepared by mixing preliminary sludge, acetate solution, sulfide solution, and tap water. For the treatment groups, electrode will be subjected to biofilm development at low voltage and thereafter the applied voltage will be adjusted to levels that is determined in Activity 1. Both the simulated sewers and receiving wells will be continuously operated for six-month. Periodical sampling of mixed liquor and composition analysis in terms of sulfur species and sludge accumulation will be conducted. The headspace gas will be monitored via hydrogen sulfide sensor with data being logged during experiment. At the end of operation, concrete test coupon surface will be examined by scanning electron microscopy for corrosion and surface matter and electrode deposition will be isolated and analyzed by X-ray diffraction for its composition.

Outcome	**Completion Date**
1. Fabricate a simulated sewer system and wastewater receiving well	*03/31/2021*
2. Operate and monitor the technology implementation in a simulated sewer system	*09/30/2021*
3. Operate and monitor the technology implementation in a simulated receiving well	*03/31/2022*

Activity 3: Techno-economic assessment of the technology **Budget: $34,329**

A techno-economic assessment of implementing the proposed sulfide remediation system will be conducted. The analysis will address the economic feasibility of the technology implementation in the MCES Metro Plant (St. Paul, MN), and the implementation in the sewer system. The cost analysis will yield capital cost and operating/maintenance costs of the treatment unit either installed in receiving well or in sewer system according to the performance and expenses data resulting from the long-term evaluation. The capital costs will include mainly equipment purchase, construction, electrode materials, and labors in the installation. The operating/maintenance cost will cover the expenses of electrical power usage, facility maintenance and labor. The benefit analysis will monetarize the odor and sulfur emission reduction from the environmental and health aspects, the decreased corrosion that results in the reduced occurrence of facility or structure failure, the potential benefits to wastewater treatment process. These considerations will be incorporated into a discounted-cash-flow capital budgeting analysis for having the treatment unit installed in Minnesota.

Outcome	**Completion Date**
1. Techno-economic assessment	*06/30/2022*

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. George Sprouse, and Mr. Mike Rieth P.E., 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.

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.

2019 Detailed Project Budget

Project Title: Electrochemical process to protect sewer systems from sulfide

IV. TOTAL ENRTF REQUEST BUDGET 3 years

BUDGET ITEM	AMOUNT
Personnel:	
Bo Hu, Project Manager (74.5% Salary, 25.5% Benefits), 5% FTE per year for three years	$ 22,802
Graduate student, Research assistant, 50% FTE	$ 145,906
Professional/Technical/Service Contracts	
Professional analysis service for water and solid samples at other UMN analytical labs	$ 9,365
Equipment/Tools/Supplies:	
Supplies for the lab experiments to purchase necessary chemicals, test kits, electrodes, and other materials	$ 15,607
Acquisition (Fee Title or Permanent Easements): N/A	$ -
Travel:	$ -
In-state travel (Mileage, lodging, and meals) to the site for collecting water samples	$ 3,122
Additional Budget Items	$ -
Publication costs for two/three papers, page charges	$ 3,122
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 199,924

V. OTHER FUNDS

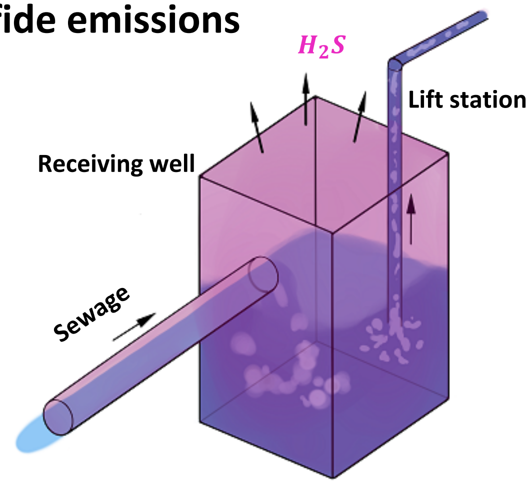
SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:	$ -	
Other State $ To Be Applied To Project During Project Period:	$ -	
In-kind Services To Be Applied To Project During Project Period	$ 82,813	*UM F&A*
Past and Current ENRTF Appropriation:		
Other Funding History:	$ -	

Electrochemical process to protect sewer systems from sulfide

Bo Hu, Bioproducts and Biosystems Enigneering, University of Minnesota

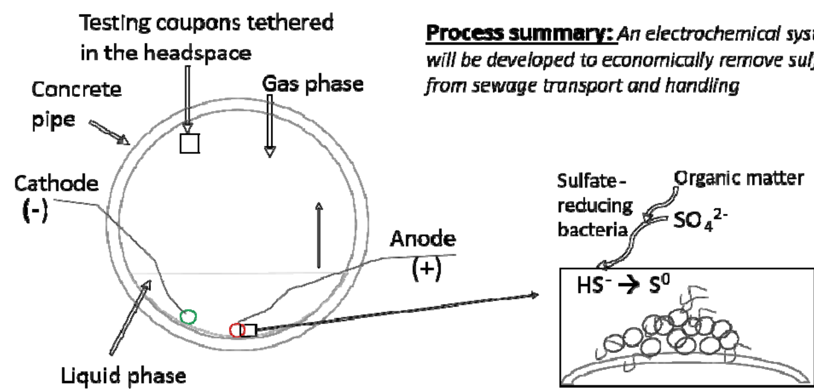
Environment and Natural Resources Trust Fund-2019

Sulfide emissions



Hydrogen sulfide (H_2S) -- Toxic, odorous, and corrosive

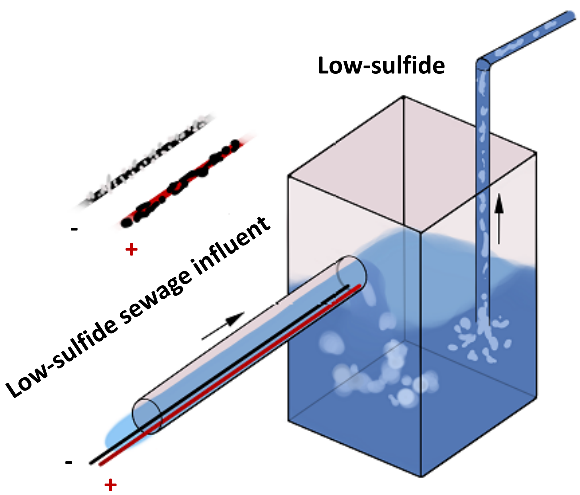
Sulfide removal principle



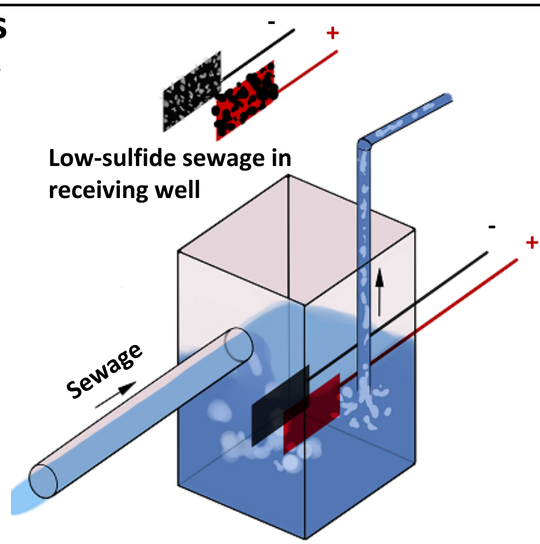
Process summary: *An electrochemical system will be developed to economically remove sulfide from sewage transport and handling*

A proposed mechanism for electrochemical sulfide removal in sewage

Testing two installation scenarios



Installation scenario I:
Sulfide removal from sewer



Installation scenario II:
Sulfide removal from receiving well

Project activities

Activity 1. Testing kinetics and efficiencies of sulfide removal reactions
Activity 2. Long-term operation in simulated sewer pipes and receiving wells
Activity 3. Techno-economic assessment of the technology

Overall outcome

An electrochemical sulfide removal process will be developed. The benefit and cost of the process will be assessed. The potential installation will protect sewer system from corrosion and decrease odor emissions from receiving well.

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 18 years of active research experience specifically in bioprocessing development, nutrient removal, 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 community microbial electrochemical septic system and a fungal biofilm system for water treatment. 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.