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

Project Title: **ENRTF ID: 077-B**

Shedding Lights to Future Septic Systems

Category: B. Water Resources

Sub-Category:

Total Project Budget: $ 361,000

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

Summary:

We want to add lights in the septic system to promote microalgae growth. It will enable septic systems to better treat domestic wastewater generated in the rural or small community.

Name: Bo Hu

Sponsoring Organization: U of MN

Job Title:

Department:

Address: 1390 Eckles Ave

St. Paul MN 55108

Telephone Number: (612) 625-4215

Email bhu@umn.edu

Web Address:

Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

project illustration to introduce lights to septic systems

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%

PROJECT STATEMENT:

While major research and industry efforts are on the large-scale centralized urban wastewater treatment systems, many small rural communities still face significant barriers to treat their domestic wastewater effectively. These homes and mid-sized facilities typically do not have the access to centralized treatment plants, they rely on subsurface sewage treatment systems, also referred to as septic systems, serving nearly 25% of the US population. The wastewater treatment of conventional septic tanks is limited since the system relies on the capacity of retaining suspended solids by accumulation and sedimentation. The solids settle as septic sludge, degraded by anaerobic bacteria and archaea to reduce its overall volume and then removed periodically. Compared to the activated sludge systems in centralized treatment plants, the septic degradation is hampered by missing of aeration and overall low efficiency of the anaerobic microbial community. Furthermore, most of the dissolved organics (soluble organic matter) and nutrients (nitrogen and phosphorous) need further soil treatment and non-treated nutrients can cause environmental problems such as eutrophication in water bodies. Consequently, the development of next generation septic tanks with higher treatment efficiencies is of importance in order to effectively treat domestic wastewater and protect the rural environment.

It is proposed in this study to introduce the light in the septic tank so that microalgae can be part of treatment options for the domestic wastewater treatment. Our research group has performed some preliminary research to inoculate phototrophic microalgae in a sequential batch reactor system and found that the overall treatment of the domestic wastewater was significantly improved, especially on the phosphorus and ammonia removal. The undergraduate student working on this project has been invited to present her results at United Nation Live @ On Demand. It is hypothesized that phototrophic microalgae can benefit the septic treatment because they produce oxygen gas, much needed for the microbes to have better degradation of organic pollutants; consume phosphorus and nitrogen during photosynthesis, therefore removing these dissolved nutrient pollutants from water; and provide additional carbon to aid in denitrification. This preferred condition of phototrophic microalgae growth can simply materialize by introducing light in the septic systems. The illuminated septic systems will especially be helpful in dealing with the increased sewage strength due to food waste disposal, and will accelerate the degradation of recalcitrant solids in sludge like fibers from toilet papers and some common medication pharmaceuticals. This study will evaluate the effect of light inclusion in the lab study on septic tank performance and solids degradation. The study will also evaluate septic tank performance in a real household septic tank with light driven by a solar panel.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: lab study of septic treatment assisted by microalgae **Budget: $112,000**

The study will start with the inclusion of microalgae in the septic tank. Based on our preliminary study, the addition of microalgae into activated sludge was found to provide improved nutrient removal from wastewater in a sequential batch reactor system as compared to a conventional centralized wastewater treatment. However, the intermittent wastewater feeding patterns and compositional variances between each waste stream of a septic system make its operation different from either a sequential batch reactor system or a centralized one. Therefore, the objective of Activity 1 is to utilize a poly-culture of microalgae and activated sludge for assisted nutrient removal in an illuminated septic tank system and analyze the efficiency and impact of such a system. The lab-scale reactors, inoculated with pre-cultivated activated sludge and microalgae strains, will be hourly fed the influents from St. Paul wastewater treatment plant with different waste streams including, food waste shredded by disposers, fibrous solids from toilet paper, common medications, etc., to represent a typical septic tank system. The effluents will be sampled and analyzed to evaluate the nutrient (mainly nitrogen and phosphorous) removal efficiency. The biogas emissions and biomass accumulations will be compared as well at a time interval of 30 days. Meanwhile, key parameters including the illumination intensity, light/dark cycles, microalgae strains, microalgae to activated sludge ratios, and influent flow rates will be optimized for the most

efficient treatment. Eventually, a lab-scale illuminated septic system will be established with improved nutrient removal from household wastewater streams.

Outcome	Completion Date
1. Treatment parameters for microalgae in the domestic wastewater treatment	Year 1 - 06/2021

Activity 2: Reactor design of septic system illuminated with lights **Budget: $120,000**

The aim of this activity is to find the reactor design so that lights can be properly inserted to provide illumination to the septic tank while the microalgae growth does not form the biofilm and block the light. To achieve this, laboratory scale septic reactors with working volumes of approximately 20 liters will be built with an insertion manhole (hand-hole). Different lighting design will be considered to be added to the manhole cover, such as illumination light position, types of lights, lighting area, and transparent materials. The evaluation of the reactors will be carried out continuously in order to select the best lighting design. The criteria to select best lighting approaches is to support robust microalgae growth and nutrient removal while resisting biofilm formation.

Outcome	Completion Date
1. Reactor design to illuminate the septic tank for microalgae growth	*Year 2 – 12/2021*
2. Evaluation via 20 litter simulated lab septic tanks	*Year 2 – 06/2022*

Activity 3: Demonstration of developed septic system and economic analysis **Budget: $129,000**

The main objective is to construct a LED light insert prototype that can be installed on a typical traditional septic tank of about 3000 gallons. We will explore the installation of a solar panel to provide the electricity for the lights. Operational parameters and design considerations will be based on the knowledge acquired from previous activities. We will work with MNDOT to choose a new site with a twin septic system so that the manhole of one of the septic tanks can be retrofitted. We will monitor and measure the septic system for 2 months, following the same approach as Activity 1 and 2. The influent flow rates, organic loading rates, and hydraulic retention times will be recorded and reactor optimized in order to have the best effluent quality. In addition, an economic assessment will be carried out by considering the cost of the system installation and operation.

Outcome	Completion Date
1. On-site demonstration	*Year 3 - 12/2022*
2. Economic analysis	*Year 3 - 06/2023*

III. PROJECT STRATEGY

A. Project Team/Partners: The research team include Dr. Bo Hu and Dr. Lingkan Ding from the Department of Bioproducts and Biosystems Engineering, and Dr. Sara Heger, extension specialist at Water Resource Center, University of Minnesota. Hu is an expert on the anaerobic digestion and will serve as the project director to manage the project, design the experiments and write the project reports. Ding, a postdoc researcher, will execute the activities and provide technical expertise. Heger will provide practical field research experience relating to septic systems, locate a demonstration site, facilitate the onsite design, and provide extension on the applications.

B. Project Impact and Long-Term Strategy: The project will have a broad impact on both academia and industry. The results will provide fundamental knowledge on how the microalgae cells can assist the biodegradation of organic pollutants, nutrients, and typical pharmaceuticals. The applications will lead to new types of septic system developments that can provide better treatment option for the small rural community.

C. Timeline Requirements: The project will be completed in 3 years, with the two year for lab-scale study and the third year for on-site demonstration, economic analysis and future implementation of this technology.

IV. LONG-TERM IMPLEMENTATION AND FUNDING: With completion of the project, we will deliver a conceptual design of new septic systems. We will collaborate with UMN Office of Technology Commercialization and actively look for commercial partners to explore the possibility for commercialization of this technology. We will also partner with Minnesota Department of Agriculture to apply the technology in the rural facilities.

Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Bo Hu
Project Title: Shedding Lights to Future Septic Systems
Organization: University of Minnesota
Project Budget: $361,000
Project Length and Completion Date: 3 years, July 1st, 2020
Today's Date: April 5th, 2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 303,000	$ -	$ 303,000
Bo Hu -PI, .08 FTE, $47,000 (73.5% salary/26.5% fringe - Will manage the project, design the experiments and write the project reports			
Sara Hager - Co-PI, 0.08 FTE, $34,000 (73.5% salary/26.5% fringe - willl provide practical field research experience relating to septic systems, locate a demonstration site, facilitate the onsite design, and provide extension on the applications			
Lingkan Ding, Research Associate - 1 FTE per year, $222,000 (73.5% salary/26.5% fringe), will execute the activities and provide technical expertise			
Professional/Technical/Service Contracts			
	$ -	$ -	$ -
Equipment/Tools/Supplies			$ -
Supplies and non-capital equipment - $29,000 -	$ 29,000		$ 29,000
	$ -	$ -	$ -
Capital Expenditures Over $5,000			$ -
A manhole will be retrofitted to have the light connected with a solar panel and installed to a testing septic tank for demonstration	$ 8,000	$ -	$ 8,000
Fee Title Acquisition			$ -
	$ -	$ -	$ -
Easement Acquisition			$ -
	$ -	$ -	$ -
Professional Services for Acquisition			$ -
	$ -	$ -	$ -
Printing			$ -
	$ -	$ -	$ -
Travel expenses in Minnesota			$ -
Travel to take manuciple wastewater from the primary effluent and to take samples at the demonstration site	$ 5,000		$ 5,000
	$ -	$ -	$ -
Other			$ -
Laboratory services	$ 16,000		$ 16,000
	$ -	$ -	$ -
COLUMN TOTAL	$ 361,000	$ -	$ 361,000

SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State:		$ -	$ -	$ -
State:		$ -	$ -	$ -
In kind: Unrecovered F&A	Secured	$ 194,000	$ -	$ 194,000
Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	**Amount legally obligated but not yet spent**	**Budget**	**Spent**	**Balance**
M.L. 2015, Chp. 76, Sec. 2, Subd 4(b)	$ -	$ 281,000	$ 281,000	$ -
M.L. 2014, Chp. 226, Sec. 2, Subd.08g	$ -	$ 258,000	$ 258,000	$ -

Shedding Lights to Future Septic Systems

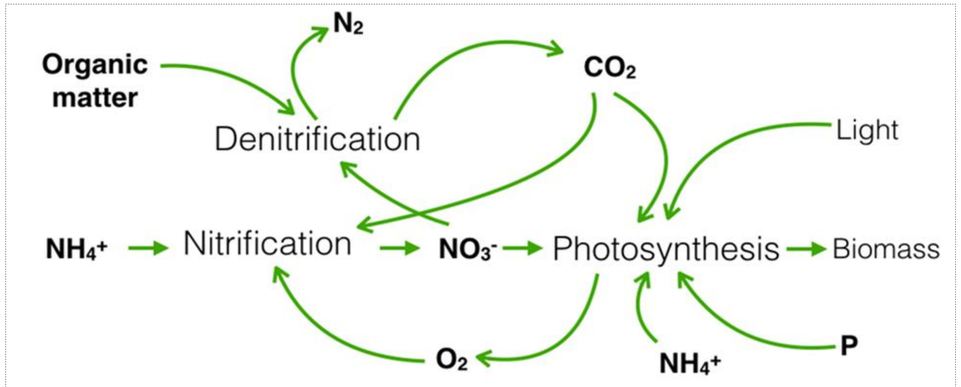
Bo Hu, Lingkan Ding, and Sara Heger
University of Minnesota

Environment and Natural Resources Trust Fund - 2020

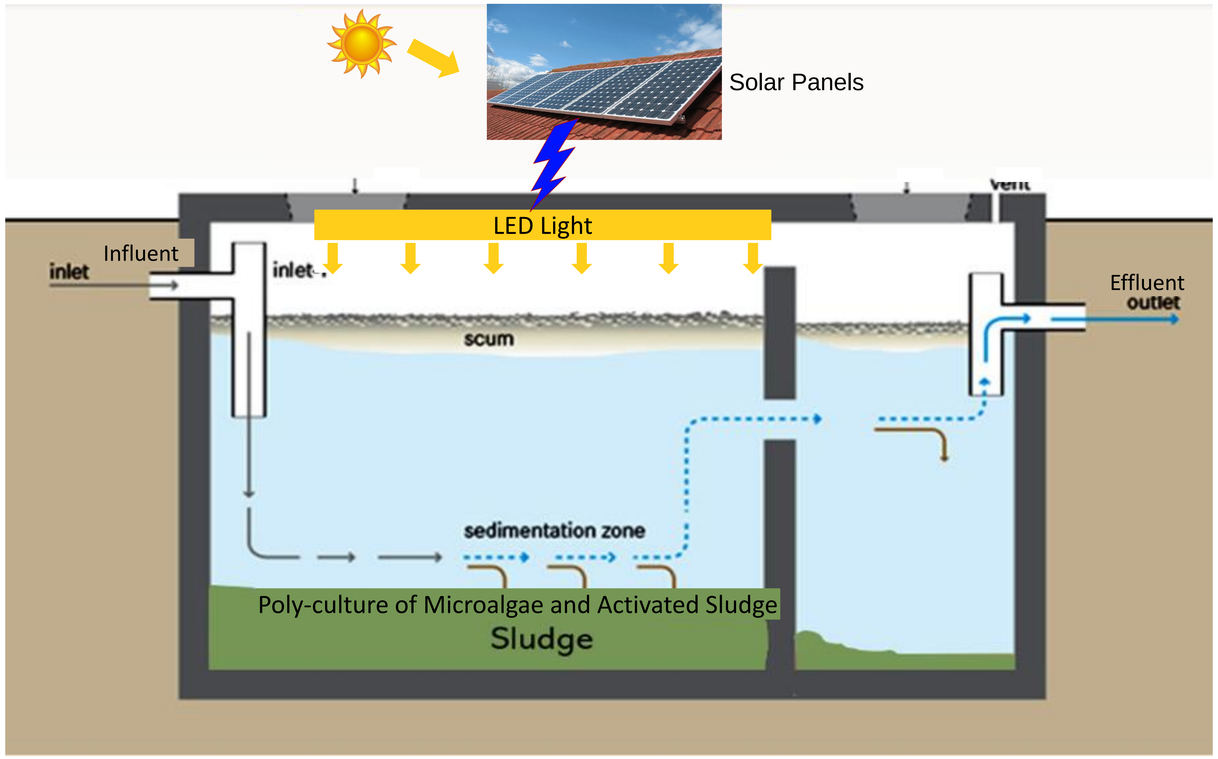
This project proposes to develop next generation illuminated septic tank systems by the inclusion of microalgae into current septic tank systems.

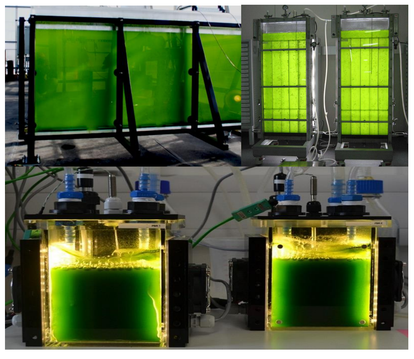
Benefits:

- Improve degradation of waste and pharmaceuticals,
- Remove soluble nutrient pollutants from entering into soil and ground water,
- Ensure better protection of rural environment.



Nitrogen and Phosphorus Recuperation by Microalgae





Lab-scale Prototype

On-site Demonstration

Proposed Activities:

Microalgae — Activated Sludge — Domestic wastewater

Microalgae Assisted Septic Treatment

Lab-scale Reactors (1-Liter)

Light Insertion Design

Reactor Design & Evaluation

Lab-scale Prototypes (20-Liter)

LED-Light Powered by Solar Panel

On-site Demonstration

Retrofitted Septic Tank (3000-Gallon)

Project Manager Qualifications

The research team will include Professor Bo Hu and his postdoc researcher Dr. Lingkan Ding from the Department of Bioproducts and Biosystems Engineering, and Dr. Sara Heger, the extension specialist at Water Resource Center, University of Minnesota.

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; Dr. Lin will assist in design and experimentation, 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.

Dr. Sara Heger is an engineer, researcher and instructor in the Onsite Sewage Treatment Program in the Water Resources Center at the University of Minnesota. Since 1999, she has been providing education and technical assistance to homeowners, small communities, onsite professionals and local units of government regarding onsite wastewater treatment. Sara coordinates the research program at the UMN and is currently, serving as the principle investigator on grants to create online owner's guides and evaluate rest stops served by septic systems. Heger is on the faculty of the Water Resources Science program, teaching *Sustainable Waste Management Engineering*. She presents at many local and national training events regarding the design, installation and management of septic systems and related research. Sara is Education Chair of the Minnesota Onsite Wastewater Association (MOWA) and the National Onsite Wastewater Recycling Association (NOWRA). Sara serves on the NSF International Committee on Wastewater Treatment Systems. She is also the chair of the Minnesota State Advisory Committee on Decentralized Systems. She has BS in Biosystems & Agricultural Engineering and a PhD in Water Resource Science.

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.