Environment and Natural Resources Trust Fund
2014 Request for Proposals (RFP)

Project Title: **ENRTF ID: 133-E**

Next Generation Septic TankSystems

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

Total Project Budget: $ 258,810

Proposed Project Time Period for the Funding Requested: 3 Years, July 2014 - June 2017

Summary:

This project aims to developing next generation septic tank systems focusing on nutrient recuperation, bioenergy generation and environmental protection by the implementation of a bio-electrochemical system.

Name: Bo Hu

Sponsoring Organization: U of MN

Address: 1390 Eckles Ave
St. Paul MN 55108

Telephone Number: (612) 625-4215

Email bhu@umn.edu and awards@umn.edu

Web Address http://bohu.cfans.umn.edu/

Location

Region: Statewide

County Name: Statewide

City / Township:

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

PROJECT TITLE: Next generation septic tank systems

I. PROJECT STATEMENT

WHY – Subsurface Sewage Treatment Systems also referred to as septic systems aim to treat sewage generated from homes and mid-sized facilities that do not have access to centralized wastewater treatment plants. Nearly 25% of the US population is served with an onsite wastewater treatment system as their primary means of wastewater treatment (U.S. EPA, 2002). The primary wastewater treatment of conventional septic tanks is limited since the system relies on the capacity of retaining suspended solids by accumulation and sedimentation. 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. Phosphorus is currently produced from non-renewable resources (mined from rocks) and is increasingly needed in order to sustain the rising food and biomass energy demand. Therefore, waste stream in the septic tanks is a great potential source to recover phosphorus. Septic tanks also emit instead of being collected powerful greenhouse gases (GHGs), such as methane (CH_4) and nitrous oxide (N_2O) to the atmosphere, as well as hydrogen sulfide (H_2S), which causes obnoxious odors and concrete corrosion. Consequently, the development of next generation septic tanks with higher treatment efficiencies is of importance in order to effectively utilize waste resources and protect the environment.

Electrochemical assisted anaerobic digestion has been recently introduced as a new alternative to improve the anaerobic digestion process. A recent lab scale preliminary study by one of the team members coupled a microbial electrolysis cell (MEC) with a digester and applied an electric field to allow *in situ* production of hydrogen (H_2) and oxygen (O_2) and therefore to increase the biogas generation due to a higher H_2 concentration in the digester. The experiments achieved the biogas production a factor of 5 higher, as well as phosphorous recuperation in about 40% from the influent wastewater accumulated on the surface of the cathode electrode and the hydrogen sulfide (H_2S) concentration in the biogas a factor of 2.5 lower than in a regular septic tank.

GOAL – This project aims to develop next generation septic systems focusing on nutrient recuperation, bioenergy generation and environmental protection by the implementation of a bio-electrochemical system.

OUTCOMES – The outcome of the project are to build a supplementary MEC unit that can be plugged into current septic tank systems in order to improve the water quality of septic tanks effluents, recuperate phosphorus nutrient that can be harvested as fertilizer, increase the production and collection of biogas for the bioenergy application and decrease the emissions of GHGs. The technology developed during this project could be useful to thousands of rural communities, especially those that do not have access to centralized wastewater treatment facilities. When communities effectively manage their wastewater treatment systems, public health and the environment are adequately protected while the community has the management structure in place to sustainably treat their wastewater over the long-term. This experimentation will be carried out at the lab and at the field, and the results obtained and long-term research data to modify current design standards will contribute to the state of the art technology within Minnesota and across the nation. In addition, capital and operational costs of the implementation of such a system can be projected and the benefits assessed.

HOW – The project will be divided in two main activities (i) Reactor optimization at lab-scale level (ii) A MEC prototype will be constructed and evaluated on an existing septic tank at a household. In addition, information collected could be used for a future decentralized wastewater treatment system for the assessment of potential environmental impacts based on compliance with current standards and environmental laws.

II. DESCRIPTION OF PROJECT ACTIVITIES

Activity 1: Reactor optimization at lab-scale level. **Budget: $124,502**

The aim of this activity is to find the most efficient reactor design in terms of quality of the effluent, nutrient recuperation and biogas production. To achieve this, laboratory scale septic tank reactors will be designed and

built with working volumes of approximately 20 liters. Different design approaches will be considered such as electrodes areas and electrode materials. A regular septic tank design will be used as a control reactor for comparison purposes. Influent flow rates, organic loading rates and hydraulic retention times will be similar to the values of current systems. The evaluation of the reactors will be carried out continuously in order to optimize operational parameters as well as the quality of influent and effluent. Chemical and physicochemical characteristics of the influent and effluents will be analyzed and compared with statewide standards.

Outcome	Completion Date
1. Lab scale septic tank design and construction	*Sep 1st, 2014*
2. The best reactor design has been chosen	*Feb 1st, 2015*
2. The operational parameters have been optimized.	*Dec 1st, 2015*

Activity 2: Prototype construction, evaluation and demonstration. **Budget: $134,308**

The main objective is to design and construct a MEC prototype that can be installed on a typical traditional septic tank of about 3000 gallons. Design considerations and operational parameters will be based on the knowledge acquired from activity 1. Following the same approach as activity 1 influent flow rates, organic loading rates and hydraulic retention times will be set as real systems and reactor optimization will be attempted in order to have the best effluent quality, the higher biogas conversion efficiency and higher recuperation of nutrients.. In addition, an economic assessment will be carried out by considering the cost of the system, the cost related with the operation of the system and the valorization of the outputs such as biogas and nutrients. Nutrients, recuperated in the form of struvite, have potential as a slow release fertilizer.

Outcome	Completion Date
4. Prototype construction.	*March 1st, 2016*
5. Prototype optimization.	*Feb 1st, 2017*
6. Evaluation of capital and operational costs	*May 31st, 2017*

III. PROJECT STRATEGY

A. Project Team/Partners

The research team will include Professor Bo Hu, Dr. Carlos Zamalloa from the Department of Bioproducts and Biosystems Engineering, and Ms. Sara Heger, the 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. Zamalloa, a postdoc researcher, has recently published one paper to couple the MEC with the septic tank systems, and he will execute the activities and provide technical expertise. Heger will provide practical field research experience relating to septic systems in MN, locate a demonstration site, facilitate the onsite design and provide extension on the applications.

B. Timeline Requirements

The project will be finished within 3 years. Regular septic systems are operated for 2-3 years before maintenance to remove the solids accumulated. Both lab-scale and household tests require long operational periods and continuous examinations in order to allow a realistic comparison with regular septic systems.

C. Long-Term Strategy and Future Funding Needs

In the long term, a MEC can be implemented in existing septic tanks in residential houses and as such, the urban population can benefit from proper wastewater treatment that protects ground and surface waters along with protecting human health. This experimentation will be carried out at laboratory level and the results obtained and long-term research data to modify current design standards will contribute to the state of the art technology within Minnesota. In addition, capital and operational costs of the implementation of such a system can be projected and the benefits assessed. This new information will be reported to existing and new wastewater professionals throughout Minnesota and beyond by our educational program; and future funding may be requested to promote the applications of this new system.

2014 Detailed Project Budget

Project Title: *[Next generation septic tank systems]*

INSTRUCTIONS AND TEMPLATE (1 PAGE LIMIT)

Attach budget, in MS-EXCEL format, to your "2014 LCCMR Proposal Submission Form".

(1-page limit, single-sided, 10 pt. font minimum. Retain bold text and DELETE all instructions typed in italics. ADD OR DELETE ROWS AS NECESSARY . If a category is not applicable write "N/A" , leave it blank, or delete the row.)

IV. TOTAL ENRTF REQUEST BUDGET *[Insert # of years for project]* **years**

BUDGET ITEM *(See "Guidance on Allowable Expenses", p. 13)*	**AMOUNT**
Personnel:	
Project director, Bo Hu will be paid to manage the project, design the experiments and write the project report. The payment will cover his one month summer salary and fringe benefits. 74.85% of payment will be the salary and 25.15% will be the fringe benefits.	$ 34,534
Postdoc researcher, Dr. Carlos Zamalloa will be paid to execute the activities and provide technical expertise. 100% of time enployment will be covered for this position by the project, including 83.28% for the salary and 16.72% for the fringe benefits.	$ 129,899
Septic system extension specialist , Ms. Sara Heger will be paid to provide practical field research experience relating to septic systems in MN, locate a demonstration site, facilitate the onsite design and provide extension on the application of the research. One month appointment will be paid with the project, including 74.84% for the salary and 25.16% for the fringe.	$ 45,376
Equipment/Tools/Supplies:	$ -
Lab scale septic tanks with MEC	$ 5,000
MEC plug-in phototype for the household	$ 10,000
Lab supply and chemicals	$ 15,455
Printing and page charges	$ 9,273
Travel: *Travel to the rural households to take samples, measure chemica compositions of waste streams, and build an improved septic tank system. 5 travels are planned per each project year and $600 per travel is budgeted.*	$ 9,273
Additional Budget Items: *In this column, list any additional budget items that do not fit above categories. List by item(s) or item type(s) and explain how number was reached. One row per type/category.*	$ -
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 258,810

V. OTHER FUNDS

SOURCE OF FUNDS	**AMOUNT**	**Status**
In-kind Services During Project Period: *Unrecovered F&A at 52% MTDC*	$ 134,581	*Secured*

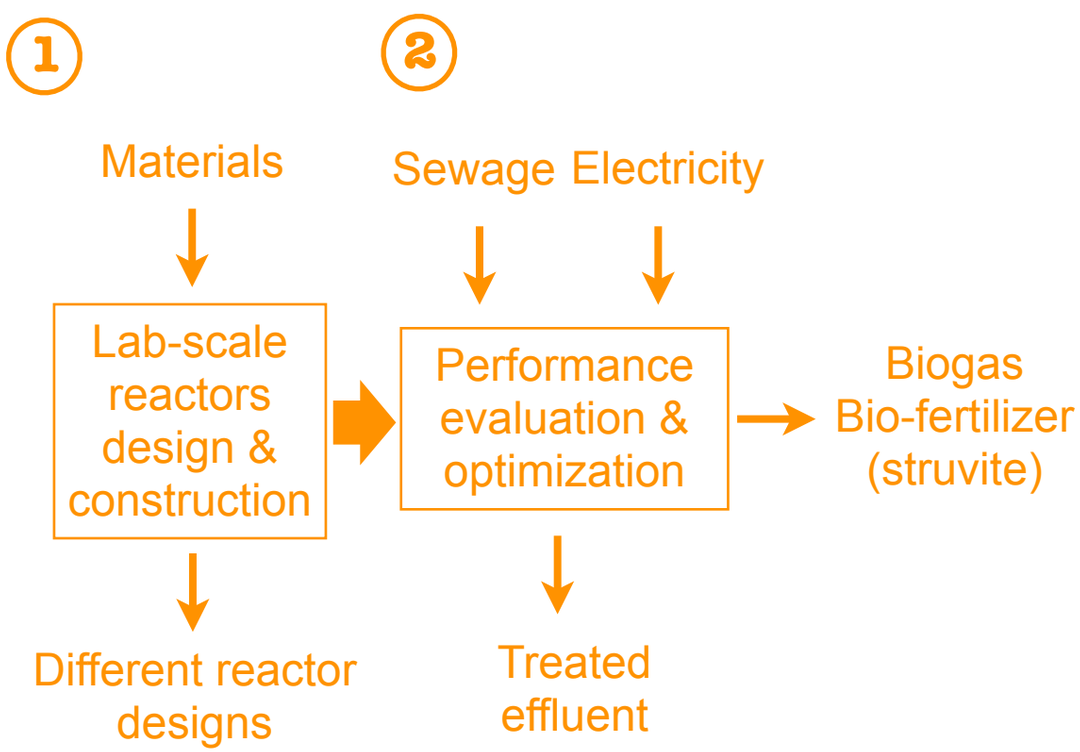
Project - graphical representation

Activity 1: Reactor optimization at lab-scale level

OBJECTIVE:

- To find the most efficient reactor design.

EXECUTION:



OUTCOMES:

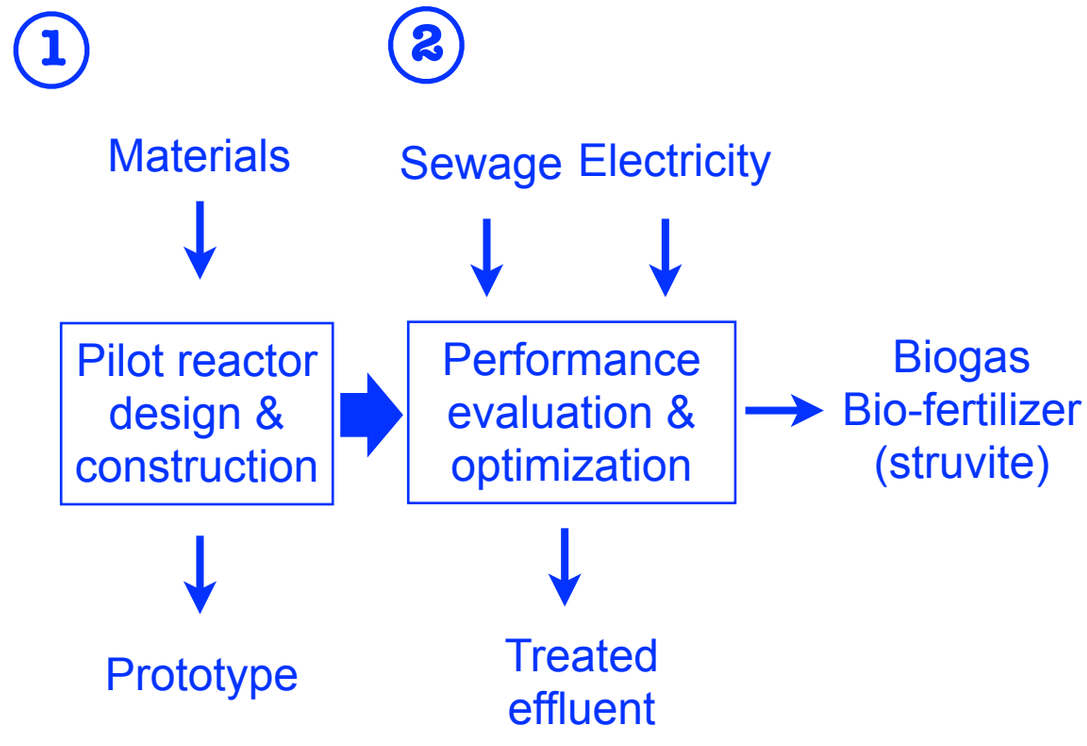
- The most efficient reactor design
- Optimized operational parameters

Activity 2: Prototype construction, evaluation and demonstration

OBJECTIVE:

- To implement the concept at pilot level.

EXECUTION:



OUTCOMES:

- Prototype construction
- Prototype optimization
- Technical and economical evaluation

Project Manager Qualifications

The research team will include Dr. Bo Hu and Dr. Carlos Zamalloa from the Department of Bioproducts and Biosystems Engineering, and Ms. Sara Heger, the extension specialist at the Water Resource Center, University of Minnesota.

With regard to technical expertise, **Dr. Bo Hu** is an Assistant Professor at the Department of Bioproducts and Biosystems Engineering of UMN. He is also a joint faculty member of Biotechnology Institute of UMN. With over 10 years of active research experience specifically in biomass utilization, fermentative conversion, and molecular biology, he has led projects on microbial oil production from waste materials via mixotrophic microalgae and oleaginous fungal fermentation, and projects to develop the modified anaerobic digestion system for biohydrogen production and its microbial community change by using 16s rDNA based microbial analysis. Hu's team at UMN has set up several standard procedures such as 16s rDNA fingerprint screening for microbial species in the wastewater treatment facilities, ITS sequences to identify oleaginous fungal species; and several conversion platforms such as pelletized fungal fermentation, solid and hemi- SolidSF to accumulate oil from lignocellulosic materials. His research ideas have been funded by many programs, especially local funding agencies such as MN Pork Board, IOWA Pork Board, MN Rapid Agricultural Response Program, etc. to tackle regional issues.

Dr. Hu's lab is located at BAE 320B, adjacent to Dr. Hu's office. The lab space is around 1000 sqft and it is equipped with two laminar flow hoods and one clean bench. The lab has all the necessary equipment and facilities for this project, including a refrigerated shaker, two open air shakers, one incubation shaker, two incubators, one fermentation bioreactor, GC-FID-TCD, PCR thermal cycler, several electrophoresis, centrifuge, and ovens. The research group can also utilize facilities and equipment at the **Biotechnology Resource Center** (BRC), on a pay-per-sample base. BRC is a 4,000 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.

Organization Description

Dr. Bo Hu joined the faculty at Department of Bioproducts and Biosystems Engineering of UMN in August 2009. 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. The collaborative partner Sara Heger works with the Onsite Sewage Treatment Program at the Water Resource Center of UMN. The program seeks to protect public health and the environment by improving wastewater treatment through research-based education and outreach for homeowners, small communities, professionals and policy-makers. UMN Sponsored Projects Administration (SPA) will be the entity authorized by the Board of Regents to manage the project agreements with LCCMR program.