Environment and Natural Resources Trust Fund
2017 Request for Proposals (RFP)

Project Title: **ENRTF ID: 063-B**

Development of a Household Decentralized Wastewater Treatment System

Category: B. Water Resources

Total Project Budget: $ 322,000

Proposed Project Time Period for the Funding Requested: 3 years, July 2017 - June 2020

Summary:

This project will study the application of high-rate activated sludge (HRAS) technology to treat the decentralized household wastewater in order to provide better treatment and energy recovery.

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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:

powerpoint slide to describe the proposed research activities

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

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

_____ Capacity Readiness _____ Leverage _______ TOTAL ______%

PROJECT TITLE: Development of a household decentralized wastewater treatment system

I. PROJECT STATEMENT

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. In addition, solids that settle undergo anaerobic digestion where most of the dissolved organics (soluble organic matter) and nutrients (nitrogen and phosphorous) are solubilized into the water phase as well as emitting powerful greenhouse gases (GHGs), such as methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) to the atmosphere. While the tank decreases the suspended solids, the slow percolation of the effluent through the soil attenuates most of the nutrients, micropollutants, and pathogens that are present in household wastewater causing potential contamination of the nearby groundwater and surface water, which may have direct consequences for human and environmental health. Several studies have shown that septic tank effluents in practice are highly variable in quality. Effluents can reach Biological Oxygen Demand values up to 480 mg/L, total suspended solids (TSS) up to 695 mg/L and ammonia levels up to 91 mg/L [2].

The high-rate activated sludge (HRAS), also known as the A-stage of the A/B process, is a technology that has recently regained popularity in Europe due to its high efficiency removing pollutants, stable at fluctuating loadings, low energy consumption, small footprint and producing a sludge with high energy content [3; 4; 5; 6]. The high-rate operation of the HRAS (SRT of <1 day, HRT of 30 min and DO of <1 mgO_2/L) can concentrate the influent particulate, colloidal, and soluble COD to a waste solids stream due to the enhancement of sludge production, bio-flocculation, biological sorption and bacterial storage. Bacterial storage also allows nitrogen and phosphorous removal through biomass assimilation [7; 8]. The sludge produced by the HRAS process has better digestion characteristics than normal secondary sludge, resulting in a lower overall sludge production when compared to a single-sludge nutrient removal process preceded by primary sedimentation [9]. The HRAS systems can be designed and operated to meet secondary effluent standards without addition of chemicals i.e. 30 mg/L BOD5 and 30 mg/L TSS.

The HRAS technology is currently installed in centralized wastewater facilities worldwide (i.e. applied in 20 full-scale facilities in Europe) mainly due to its capacity to improve energy balances. Despite its potential for decentralized applications, there has not been much focus on the development of a stand-alone system for decentralized wastewater treatment using HRAS technology. The objective of this work is to develop a state-of-the-art decentralized wastewater system for the primary treatment of domestic wastewater. The first stage of the system will use the HRAS process followed by sedimentation to concentrate organics and in the second stage, the sludge produced will be subjected to anaerobic digestion for the production of energy and stabilization of solids. The effluents of this process will be compared with traditional septic tank systems.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Lab-scale experiments **Budget: $104,000**

The objective of this task is to build a lab-scale reactor and optimize its operational parameters. The HRAS system will consist of two compartments (i) a Continuous Stirred Tank Reactor (CSTR) and (ii) a settling tank. The combination of the CSTR and the settling tank enhances the development of a unique microbial community that allows bio-flocculation and sorption of pollutants into the sludge while removing nutrients (nitrogen and phosphorous) by assimilation into the sludge cell biomass. The most important operational parameters such as SRT, MLSS, HRT and DO will be studied in order to maximize the biomass accumulation of bio-flocculant producing bacteria and removal of pollutants. Solids from the settling tank will be recirculated to the CSTR reactor in order to allow a solid retention time (SRT) of about 2.5 hours while keeping the mixed liquor suspended solids (MLSS) about 2g/L. Subsequently, a fraction of the sludge produced will be subjected to anaerobic digestion for the production of energy and the stabilization of solids. The anaerobic digester will be operated under mesophilic conditions (35 ±2 °C) at an HRT of 20 days. Biogas production and quality will be monitored and analyzed. The operational parameters in HRAS system will directly impact the digestibility of the sludge produced, hence affecting the anaerobic digester.

Outcome	Completion Date
1. Lab-scale reactors construction, set up and start-up	*September 30, 2017*
2. Identify optimal operational parameters and system design	*May 31, 2018*
3. Compare performance with previous findings.	*June 30, 2018*

Activity 2: Prototype construction **Budget: $102,000**

The main objective of this task is to build a compact lab-scale prototype including the identification of the most suitable sensors and process control. A compact system prototype will consist of the application of HRAS and anaerobic digestion technology to one container including sensors and automatization, necessary to ensure optimal operation and good quality of the effluent. Because of the operational parameters and technologies used, the prototype footprint will be lower than for standard septic tanks.

Outcome	Completion Date
1. Develop a compact system prototype	*December 30, 2019*
2. Compare performance with lab experiments and septic tanks	*April 31, 2020*

Activity 3: Techno-economic evaluation **Budget: $116,000**

A techno-economical analysis will be carried out and the results will be compared with traditional septic tanks in terms of overall performance, effluent quality, energy consumption, environmental impact of the system (i.e. GHG's and footprint) and costs (capex and opex). Biogas generated from the process will be directly combusted to minimize the greenhouse effects of methane.

Outcome	Completion Date
1. Assess techno-economic viability	*June 30, 2020*

III. PROJECT STRATEGY

A. Project Team/Partners

Dr. Bo Hu (UMN), an associate Professor of the Department of Bioproducts and Biosystems Engineering., will be the team leader. Dr. Hu will manage the research activities for this project. Dr. Hu directed an earlier LCCMR project on novel septic tank development for nutrient and energy capture. Dr. Carlos Zamalloa, a Research Associate in the Department of Bioproducts and Biosystems Engineering, will carry out reactor design, experiments and techno-economic analysis.

B. Project Impact and Long-Term Strategy

It is expected that our system will allow a better and a more stable treatment of domestic wastewater than septic systems with a lower waste production, lower footprint and potential energy production. The knowledge acquired during this project might propose a novel alternative to current septic systems leaving a positive impact on rural communities and the environment in Minnesota. In addition, it might allow the exploration of more advanced wastewater technologies for the production of an effluent with higher quality for water reuse, protection of the environment and public health. About one quarter of all single-family housing units in the United States are beyond the reach of public sewer systems, hence more than 26 million people are served by decentralized septic systems [1]. It is critical to rethink how to treat domestic sewage that is not being treated by centralized wastewater treatment plants while aiming to maximizing energy and nutrient recovery from sewage and minimizing waste production in order to protect public health, preserve valuable water resources and have a positive impact on the environment.

C. Timeline Requirements

It is planned that the duration of this project will be for a period of three years including the two main activities.

2017 Detailed Project Budget

Project Title: *Development of a household decentralized wastewater treatment system*

IV. TOTAL ENRTF REQUEST BUDGET 3 years

BUDGET ITEM *(See "Guidance on Allowable Expenses", p. 13)*	**AMOUNT**	
Personnel:		$ 271,000
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. 75.32% of payment will be the salary and 24.68% will be the fringe benefits.	$ 39,950	
Postdoc researcher, Dr. Carlos Zamalloa will be paid to execute the activities and provide technical expertise. 50% of time employment will be covered for this position by the project for three years. The budget includes 82.30% for the salary and 17.70% for the	$ 96,722	
A graduate student will be paid to collect experimental data. 50% of time employment will be covered for this position by the project for three years. The student stipend is based on the UMN graduate student rate.	$ 134,328	
Professional/Technical/Service Contracts:		$ 10,000
Professional service is needed to provide chemical analysis for some parameters we cannot measure in our lab, for instance, the antibiotic concentrations in the septic	$ 10,000	
Equipment/Tools/Supplies:		$ 35,000
One CSTR reactor will be constructed for the small scale lab test.	$ 6,000	
Prototype reactor	$ 10,000	
Supply and chemicals to be used to work on the experiments in the lab and field	$ 19,000	
Travel:		$ 3,000
Travel to the municiple wastewater treatment plant. Ten travels are planned per each project year and $100 is budgeted per travel per year	$ 3,000	
Additional Budget Items:		$ 3,000
Page charges for publications	$ 3,000	
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =		$ 322,000

V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

SOURCE OF FUNDS	**AMOUNT**	**Status**
Other Non-State $ To Be Applied To Project During Project Period: *Indicate any additional non-state cash dollars secured or applied for to be spent on the project during the funding period. For each individual sum, list out the source of the funds, the amount, and indicate whether the funds are secured or pending approval.*	$ -	*Indicate: Secured or Pending*
Other State $ To Be Applied To Project During Project Period: *Indicate any additional state cash dollars (e.g., bonding, other grants) secured or applied for to be spent on the project during the funding period. For each individual sum, list out the source of the funds, the amount, and indicate whether the funds are secured or pending approval.*	$ -	*Indicate: Secured or Pending*
In-kind Services To Be Applied To Project During Project Period: *Unrecovered F&A*	$ 167,000	*Secured*
Funding History: *Indicate funding secured but to be expended prior to July 1, 2016, for activities directly relevant to this specific funding request, including past and current ENRTF funds. State specific source(s) of fund and dollar amount.*	$ -	
Remaining $ From Current ENRTF Appropriation: *Specify dollar amount and year of appropriation from any current ENRTF appropriation for any directly related project of the project manager or organization that remains unspent or not yet legally obligated at the time of proposal submission. Be as specific as possible. Indicate the status of the funds.*	$ -	*Indicate: Unspent? Legally Obligated? Other?*

Development of a Household Decentralized Wastewater Treatment System

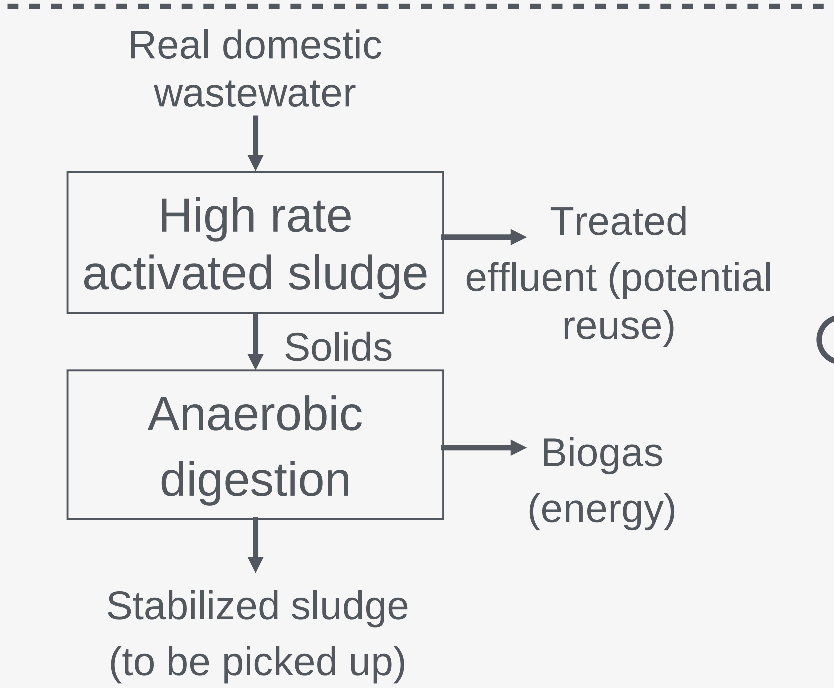
Bo Hu and Carlos Zamalloa, Bioproducts and Biosystems Engineering, University of Minnesota

Activity one

Lab-scale experiments

Objective: Optimize reactor operation and system design

Execution



Outcomes

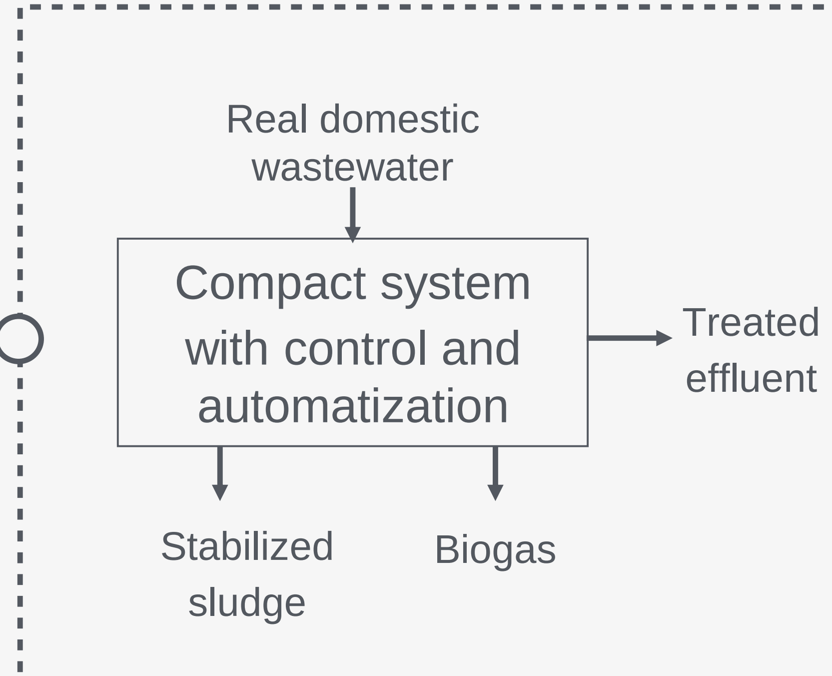
- Identify optimal operational parameters and system design
- Compare performance with previous findings.

Activity two and three

Prototype construction and techno-economic evaluation

Objective: Build a compact prototype and evaluate performance

Execution



Outcomes

- Develop a compact system prototype
- Compare performance with lab experiments and septic tanks
- Assess techno-economical viability

Project Manager Qualifications

The research team will include Dr. Bo Hu and Dr. Carlos Zamalloa from the Department of Bioproducts and Biosystems Engineering, University of Minnesota.

With regard to technical expertise, **Dr. Bo Hu** is an Associate 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, LCCMR, 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, HPLC, IC, 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. MN Sponsored Projects Administration (SPA) will be the entity authorized by the Board of Regents to manage the project agreements with LCCMR program.