**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**

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| **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.

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| **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.

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| **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.

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| **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.