

**Environment and Natural Resources Trust Fund**

# 2021 Request for Proposal

## **General Information**

**Proposal ID:** 2021-349

**Proposal Title:** Novel Microalgae Attached Growth for Animal Wastewater Treatment

## **Project Manager Information**

**Name:** Roger Ruan

**Organization:** U of MN - College of Food, Agricultural and Natural Resource Sciences

**Office Telephone:** (612) 625-1710

**Email:** ruanx001@umn.edu

## **Project Basic Information**

**Project Summary:** To develop an attached growth method for fast cultivation and efficient harvesting of microalgae in the anaerobically digested manure for nutrients removal and animal feed production.

**Funds Requested:** $760,000

**Proposed Project Completion:** 2024-06-30

**LCCMR Funding Category:** Water Resources (B)

## **Project Location**

**What is the best scale for describing where your work will take place?** Statewide

**What is the best scale to describe the area impacted by your work?** Statewide

**When will the work impact occur?** During the Project and In the Future

## **Narrative**

**Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.**

In Minnesota, agriculture is the second-largest industry and produces a large amount of wastewater. The livestock waste (such as dairy and swine manure) contributes a large proportion to this wastewater. For example, the Concentrated Animal Feeding Operations (CAFOs, over 1,000 animal units) produce more manure by weight than 30,000,000 people, which is a severe concern to the environment. Improperly operated feedlots and the manure created there can result in heavily contaminated lakes or rivers that are unhealthy for humans and animals. Meanwhile, livestock wastewater contains large amounts of nutrients which should be reused, recycled and reclaimed (3R).
In recent 20 years, microalgae have been widely used in many areas and attracted significant attention. Among these, coupling algal cultivation and agricultural wastewater treatment is a hotspot in the research and development efforts focused on reuse. Algae generally show effective in wastewater treatment and biomass accumulation, while the downstream process of algal harvest and biomass use still remains a major issue. The main existing methods for algal biomass harvest are adding chemicals (flocculation, coagulation, etc.) or using physical processes (centrifugation, filtration, etc.). These methods may be effective for algal harvest under certain circumstances, but generally bring new burdens to the process, such as chemical residuals, energy waste, running cost, labor increase, process complication, and efficiency reduction, etc. Therefore, finding an easy-to-operated and cost-effective method for the downstream process to achieve the 3R requirement is extremely essential.

**What is your proposed solution to the problem or opportunity discussed above? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and Milestones.**

In order to solve these issues, we propose to use natural materials which can serve as both algal growth support and animal feed. According to the characteristics and amount of animal wastewater, an integrated technology is expected to build for simultaneous nutrients reduction, biomass recovery and animal feed production.
In this process, anaerobically digested (AD) animal manure wastewater will be used as the media to provide nutrients and water for the algal growth. Plant based materials that can be used as animal feeds directly with little treatment (such as drying) will be selected for algal cells to attach on and grow. Also, searching appropriate high valued algal strains which is easy to attach on the natural materials and have strong tolerance to wastewater. This process can be developed into a centralized and in-situ treatment application co-located with the wastewater source (near the livestock), integrating animal manure anaerobically digested process, algal AD wastewater treatment, algae harvest and animal feed production. This system would both simplify downstream process of algal harvest and biomass reuse, which would improve the economic outlook of the existing process. We expect that the natural material with algal attached on could be a new nutrition source as animal feeds which are fresh, cheap, safe, effective, nutritional and easy to obtain.

**What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state’s natural resources?**

The outcomes of the project will provide the animal production operators a tool to treat animal manures and produce animal feeds. This, if proven cost effective, will make animal wastewater treatment affordable and thus promote greater practice of animal wastewater treatment and reduce environmental impacts and improve economic outlook of animal production operations.

## **Activities and Milestones**

### **Activity 1: Plant-based growth support material and algae strain selection for the optimal combination**

**Activity Budget:** $200,000

**Activity Description:**Several plant-based materials and algal strains will be selected for fundamental study using artificial culture media. The criteria for support material selection are following desirable properties: suitability for animal feed, adequate resistance to biodegradation (won’t disintegrate significantly during cultivation cycle), adequate shape and mechanical strength, suitable surface affinity with algal cells, etc. For algal stains, they should be easy to attach and grow on the support materials and tolerant to high level of salt and other pollutants, and have high yield and adequate nutrients for animals , etc. Experiments will be designed to study the performance of different combinations of support materials and algae strains. The optimized material and algae combination will be selected and used for the next step.

**Activity Milestones:**

|  |  |
| --- | --- |
| **Description** | **Completion Date** |
| Plant based growth support materials are collected and characterized | 2021-12-31 |
| Algae strains are selected and their growth performance on selected support materials are evaluated | 2022-12-31 |
| Combination of support material and algae strain is optimized | 2022-12-31 |

### **Activity 2: : Test the algae-material combinations in AD wastewater and evaluate the feasibility of feed application of the harvested biomass**

**Activity Budget:** $200,000

**Activity Description:**The optimized algae-material combinations will be tested in the AD swine manure in lab-scale. The removal of nutrients (TN, TP and COD reduction, etc.), biomass accumulation under different cultivation condition (temperature, pH, etc.) will be evaluated. Then harvested biomass (support material and algae cells attached on the support materials) will be analyzed for nutrients (DHA, fatty acid, etc.) and safety parameters (heavy metal, bacterial, etc.) to evaluate for the potentials as animal feeds.

**Activity Milestones:**

|  |  |
| --- | --- |
| **Description** | **Completion Date** |
| AD wastewater treatment effects and biomass accumulation will be evaluated | 2023-06-30 |
| Cultivation condition will be tested and combinations will be further optimized | 2023-09-30 |
| Components valuation and safety of harvested biomass will be analyzed | 2023-09-30 |

### **Activity 3: Design, fabricate, and test pilot-scale system on farm**

**Activity Budget:** $360,000

**Activity Description:**With the process optimized, a small pilot-scale systems will be designed according to the actual local livestock’s real wastewater qualities, operation conditions, etc. The pilot-scale systems will be operated on an animal farm for 6-8 week. The data obtained from the pilot operation will be analyzed to improve this technology.

**Activity Milestones:**

|  |  |
| --- | --- |
| **Description** | **Completion Date** |
| Scale up parameters will be developed | 2023-09-30 |
| Pilot-scale system will be designed, built, and adjusted | 2024-03-31 |
| Operation data will be analyzed and technology improvement and demonstration will be completed | 2024-06-30 |

## **Project Partners and Collaborators**

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Organization** | **Role** | **Receiving Funds** |
| Yanling Cheng | University of Minnesota | co-PI | No |
| Paul Chen | University of Minnesota | co-PI | Yes |

## **Long-Term Implementation and Funding**

**Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this be funded?**The proposed technology would be an in situ integrated processing system for the CAFOs wastewater treatment which will reuse and recycle the nutrients on farm. This system will be a cost-effective and energy-saving way for nutrients reduction, biomass collection, and animal foods production. In the long-term, we will cooperate with CAFOs to build the manure treatment system using this technology. Findings from this project will be used to obtain additional funds from USDA.

## **Other ENRTF Appropriations Awarded in the Last Six Years**

|  |  |  |
| --- | --- | --- |
| **Name** | **Appropriation** | **Amount Awarded** |
| Demonstrating Innovative Technologies to Fully Utilize Wastewater Resources | M.L. 2014, Chp. 226, Sec. 2, Subd. 08c | $1,000,000 |
| Development of Innovative Sensor Technologies for Water Monitoring | M.L. 2016, Chp. 186, Sec. 2, Subd. 04j | $509,000 |

## **Project Manager and Organization Qualifications**

**Project Manager Name:** Roger Ruan

**Job Title:** Professor and Director

**Provide description of the project manager’s qualifications to manage the proposed project.**Dr. Roger Ruan, Professor and Director, Center for Biorefining and Department of Bioproducts and Biosystems Engineering, University of Minnesota, Fellow of ASABE and Fellow of IFT, is the project manager of the proposed project. Dr. Ruan’s research focuses on renewable energy technologies, solid and liquid waste treatment and utilization, and environmental engineering. Specifically, he has conducted research and published his findings in the areas of municipal, agricultural, and industrial wastewater treatment and utilization through novel anaerobic digestion, microalgae cultivation, and hydroponic cultivation, biomass and solid wastes (including plastics) gasification and pyrolysis, airborne pathogen disinfection, catalysis, non-thermal plasma, ammonia synthesis, etc. He is a top-cited author in the area of agricultural and biological sciences with an h-index of 63, i10-index of 255, and over 15,400 citations, and has received over 180 projects totaling over $45 million in various funding for research, including major funding from USDA, DOE, DOT, DOD, LCCMR, and industries. He was the project manager of several earlier LCCMR funded projects which resulted in the issuance of a US patent and licensing of a technology. Therefore he has the technical expertise and project management experience to ensure the execution of proposed projects.

**Organization:** U of MN - College of Food, Agriculture and Natural Resource Sciences

**Organization Description:**The Center for Biorefining is a University of Minnesota research center and help coordinate the University efforts and resources to conduct exploratory fundamental and applied research; provide education on bioenergy, biochemicals and biomaterials; stimulate collaboration among the University researchers, other public sector investigators, and private investigators involved in biobased production technology development; promote technology transfer to industries; and foster economic development in rural areas. The Center’s research programs are founded by DOE, USDA, DOT, DOD, LCCMR, IREE, Xcel Energy, and other federal and state agencies, NGOs, and private companies. The Center is equipped with state of the arts analytical instruments, and processing facilities ranging from bench to pilot scale.

## **Budget Summary**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Category / Name** | **Subcategory or Type** | **Description** | **Purpose** | **Gen. Ineli gible** | **% Bene fits** | **# FTE** | **Class ified Staff?** | **$ Amount** |
| **Personnel** |  |  |  |  |  |  |  |  |
| Paul Chen |  | Co-Principal Investigator |  |  | 36.5% | 0.48 |  | $64,621 |
| Post Doc |  | Researcher |  |  | 25.4% | 3 |  | $193,799 |
| Roger Ruan |  | Principal Investigator |  |  | 36.5% | 0.12 |  | $24,328 |
| Graduate Research Assistant |  | Research Assistant |  |  | 45% | 1.5 |  | $150,933 |
| Graduate Research Assistant |  | Research Assistant |  |  | 45% | 1.5 |  | $150,933 |
|  |  |  |  |  |  |  | **Sub Total** | **$584,614** |
| **Contracts and Services** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Equipment, Tools, and Supplies** |  |  |  |  |  |  |  |  |
|  | Tools and Supplies | Materials and lab supplies including chemicals for analysis, growth support materials, consumable supplies for analytical instruments, algae strains, fertilizers, filtering materials, glassware, etc. | For running experiments and operating the systems. |  |  |  |  | $19,386 |
|  | Equipment | Components for fabrication of experimental apparatus and demonstration system, including bench scale reactors, multi-level reactors, light source, pumps and flow control, pipes, liquid-solid separators, biomass harvest unit, filtration units | To fabricate experimental apparatus and small system for running experiments, conducting performance analysis, and demonstration |  |  |  |  | $150,000 |
|  |  |  |  |  |  |  | **Sub Total** | **$169,386** |
| **Capital Expenditures** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Acquisitions and Stewardship** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Travel In Minnesota** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Travel Outside Minnesota** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Printing and Publication** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Other Expenses** |  |  |  |  |  |  |  |  |
|  |  | Repairs & Maintenance | Repairs & Maintenance of analytical instruments |  |  |  |  | $6,000 |
|  |  |  |  |  |  |  | **Sub Total** | **$6,000** |
|  |  |  |  |  |  |  | **Grand Total** | **$760,000** |

### **Classified Staff or Generally Ineligible Expenses**

|  |  |  |  |
| --- | --- | --- | --- |
| **Category/Name** | **Subcategory or Type** | **Description** | **Justification Ineligible Expense or Classified Staff Request** |

### **Non ENRTF Funds**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Category** | **Specific Source** | **Use** | **Status** | **Amount** |
| **State** |  |  |  |  |
|  |  |  | **State Sub Total** | **-** |
| **Non-State** |  |  |  |  |
|  |  |  | **Non State Sub Total** | **-** |
|  |  |  | **Funds Total** | **-** |

## **Attachments**

### **Required Attachments**

#### **Visual Component**

File: [a02a17f6-5d6.pdf](https://lccmrprojectmgmt.leg.mn/media/map/a02a17f6-5d6.pdf)

#### **Alternate Text for Visual Component**

The visual shows a process flow diagram, pictures of attached growth lab apparatus and growth characteristics, and nutrient removal data.

### **Optional Attachments**

#### **Support Letter or Other**

|  |  |
| --- | --- |
| **Title** | **File** |
| UMN authorization letter | [c5dd9a42-7b8.pdf](https://lccmrprojectmgmt.leg.mn/media/attachments/c5dd9a42-7b8.pdf) |
| UMN financial audit report | [6a064b5a-097.pdf](https://lccmrprojectmgmt.leg.mn/media/attachments/6a064b5a-097.pdf) |

## **Administrative Use**

**Does your project include restoration or acquisition of land rights?**
 No

**Does your project have patent, royalties, or revenue potential?**
 Yes,

 • Patent, Copyright, or Royalty Potential

**Does your project include research?**
 Yes

**Does the organization have a fiscal agent for this project?**
 No