

**Environment and Natural Resources Trust Fund**

# 2021 Request for Proposal

## **General Information**

**Proposal ID:** 2021-346

**Proposal Title:** Treatment of Petrochemical Wastewater Using Photocatalysis and Algae

## **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:** Develop a photocatalysis based technology for recovery of nutrients from petrochemical wastewater and cultivation of algal biomass feedstock for production of biofuels, biochemicals, and biomaterials.

**Funds Requested:** $559,000

**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.**

Large amounts of organic pollutants are being released from Minnesota textile, paint, and leather manufacturers into local water bodies. In 2018, 3M company alone was subjected to a suit filed by the state of Minnesota for $850 million, because the industry has discharged tons of wastewater including persistent organic pollutants. The aquatic systems and human health may be seriously affected by these organic effluents, which are extremely difficult to be degraded or eliminated by nature. Biological methods, chemical precipitation, photocatalysis treatment, and membrane filtration have been proposed for wastewater treatments.

**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.**

Photocatalysis treatment shows strong potential for the degradation of organic pollutants. TiO2 based photocatalyst was one of the most effective catalysts for the removal of organic chemicals particularly dyes and phenolic compounds from aqueous solutions. The photocatalytic performance can be dramatically enhanced under the intense pulsed light (IPL) as it is a much more efficient and intense light source than traditional UV light source. Petrochemical wastewater can be degraded into less or non-toxic chemicals first, then the nutrient can be removed, recovered and utilized by microalgae, and finally the microalgae biomass can be utilized for fuels, materials and chemicals production (Figure 1). The objectives of the project are to (1) design an experimental catalytic IPL system, (2) evaluate the effects of different treatment processing on organic pollutant degradation, as well as monitoring the growth and biomass production of the potential microalgae in the treated wastewater, (3) further modify and optimize the catalytic IPL based on degradation results, (4) evaluate the energy consumption and environmental impacts of the technology, (5) fill the knowledge gap between the commercial application and demonstration through the proposed R&D.

**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 key outcome of the project is a photocatalysis process for treatment of petrochemical wastewater enhanced through catalyst modification and use of activation light. The treated wastewater is suitable for algal biomass production, which further removes nutrients and provides feedstock for production of biofuels, biochemicals, and biomaterials. These outcomes help mitigate petrochemical wastewaters prevent pollution of our state’s waters and lands.

## **Activities and Milestones**

### **Activity 1: Scale up an integrated system of catalytic IPL and microalgae cultivation**

**Activity Budget:** $200,000

**Activity Description:**We will scale up the optimized process and design an integrated system for cIPL treatment and algae cultivation. A small pilot scale facility will be developed and tested. We will conduct systematic studies using the facility and generate mass and energy balance and emission data.

**Activity Milestones:**

|  |  |
| --- | --- |
| **Description** | **Completion Date** |
| The process will be scaled up and a small pilot production system will be fabricated | 2023-03-31 |
| The pilot system will be tested and mass and energy balance data will be generated | 2023-06-30 |
| Field demonstration of the system will be conducted | 2023-12-31 |

### **Activity 2: Assemble a lab-scale Cipl apparatus and investigate the effects of process variables on petrochemical wastewater degradation and microalgae cultivation**

**Activity Budget:** $200,000

**Activity Description:**Organic pollutant degradation via different cIPL has been explored in our lab; the potential intermediate degradation products have also been detected; the comparison among petrochemical wastewater under different catalytic IPL dose was conducted; a coating method to coat TiO2 nanoparticle onto substrates was adopt; several potential microalgae species are able to grow in the catalytic IPL treated wastewater were selected. In this activity, researchers in Center for Biorefining (CB) and BBE will conduct an objective-oriented laboratory work to expand our knowledge base on some of the key parameters to develop optimized process conditions and search for higher efficiency TiO2 based photocatalyst to reduce the total photocatalytic degradation time.

**Activity Milestones:**

|  |  |
| --- | --- |
| **Description** | **Completion Date** |
| A lab scale catalytic IPL system will be developed | 2021-12-31 |
| Key process variables on organic pollutant degradation and microalgae growth will be analyzed. | 2022-03-31 |
| TiO2 based photocatalysts and degradation mechanisms under catalytic IPL will be explored | 2022-06-30 |

### **Activity 3: Evaluate environmental impacts and economic performance**

**Activity Budget:** $159,000

**Activity Description:**The mass and energy balance data together with emission data will be used to evaluate the environmental and economic performance using mathematics models. This evaluation will provide good assessment of the environmental impact of the proposed technology. Further R&D efforts and commercialization strategy will be recommended.

**Activity Milestones:**

|  |  |
| --- | --- |
| **Description** | **Completion Date** |
| The energy efficiency, cost, and emission will be evaluated | 2023-12-31 |
| Environmental impacts will be assessed | 2024-06-30 |
| Further R&D and commercialization strategy will be recommended | 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?**New scientific knowledge on petrochemical wastewater degradation and nutrient recovery will be acquired through research, and the demonstration will help raise significant interests from the public. We will seek industry partners and private, state, and federal funding to further develop and eventually commercialize the technology.

## **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** |  |  |  |  |  |  |  |  |
| Roger Ruan |  | Principal Investigator |  |  | 36.5% | 0.12 |  | $24,328 |
| Post Doc |  | Researcher |  |  | 25.4% | 3 |  | $193,799 |
| Paul Chen |  | Co-Principal Investigator |  |  | 36.5% | 0.48 |  | $64,621 |
| Graduate Research Assistant |  | Research Assistant |  |  | 45% | 1.5 |  | $150,933 |
|  |  |  |  |  |  |  | **Sub Total** | **$433,681** |
| **Contracts and Services** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Equipment, Tools, and Supplies** |  |  |  |  |  |  |  |  |
|  | Equipment | Components for fabrication of experimental apparatus, including reactors, power supply, pulsed light fixture, UV light, mixer, tanks, pumps, control, etc. | To fabricate experimental apparatus and small system for running experiments, conducting performance analysis, and demonstration |  |  |  |  | $100,000 |
|  | Tools and Supplies | Materials and lab supplies including chemicals for analysis, catalysts, consumable supplies for analytical instruments, algae strains, glassware, etc. | For running experiments and operating the systems. |  |  |  |  | $19,319 |
|  |  |  |  |  |  |  | **Sub Total** | **$119,319** |
| **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 and Maintenance | Repairs and Maintenance of analytical instruments |  |  |  |  | $6,000 |
|  |  |  |  |  |  |  | **Sub Total** | **$6,000** |
|  |  |  |  |  |  |  | **Grand Total** | **$559,000** |

### **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: [e21de52b-a0b.pdf](https://lccmrprojectmgmt.leg.mn/media/map/e21de52b-a0b.pdf)

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

The process flow diagram describes nutrient recovery from petrochemical wastewater and potential application. Petrochemical wastewater is first degraded by catalytic intense pulsed light. Alternative light source such as pulsed LED light can be utilized to reduce energy consumption. Then the cIPL pretreated wastewater is used for microalgae cultivation. The microalgae biomass can be refined and used for fuels, materials, and chemicals production.

### **Optional Attachments**

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

|  |  |
| --- | --- |
| **Title** | **File** |
| UMN authorization letter | [23c3a35b-869.pdf](https://lccmrprojectmgmt.leg.mn/media/attachments/23c3a35b-869.pdf) |
| UMN financial audit report | [b8ea165c-502.pdf](https://lccmrprojectmgmt.leg.mn/media/attachments/b8ea165c-502.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