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

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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. Ineligible	% Benefits	# FTE	Classified 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

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
UMN financial audit report	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?

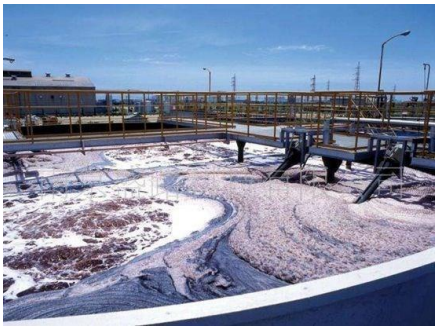
Yes

Does the organization have a fiscal agent for this project?

No

Figure 1. Nutrient recovery from petrochemical wastewater and application

Petrochemical wastewater



Catalytic intense pulsed light (cIPL) treatment system

cIPL pretreated wastewater is used for microalgae cultivation

Refined biomass is used for fuels, materials and chemicals production