Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-237

Proposal Title: Converting Toxic Compounds to Fuels Using Solar Energy

Project Manager Information

Name: Kathryn Fixen

Organization: U of MN - College of Biological Sciences

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Project Basic Information

Project Summary: Photosynthetic bacteria can use energy from light to convert toxic compounds into valuable commodities. We will determine how to stimulate this activity in low-cost wastewater lagoons where these bacteria thrive.

Funds Requested: $171,000

Proposed Project Completion: 2023-06-30

LCCMR Funding Category: Small Projects (H)
Secondary Category: Water Resources (B)

Project Location

What is the best scale for describing where your work will take place?
Region(s): Metro

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

When will the work impact occur?
In the Future

Narrative

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

Halogenated aromatic compounds (HACs) such as PCBs, chlorinated benzenes, and some pesticides can enter Minnesota waterways through industrial effluents, agricultural use, and accidents that can occur during transport of these chemicals. HACs affect the health of wildlife that inhabit these sites and have been linked to cancer and other health issues in humans. HACs are also extremely stable and persist for a long time in the environment as they are slowly degraded by microorganisms. This ability to persist in the environment means that even through legislative action to limit the use of these compounds, sites contaminated by HACs will continue to be a problem for Minnesota. There is a critical need to find new, low-cost technologies to speed up removal of these compounds.

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.

Microorganisms in the environment can breakdown HACs, such as PCBs and pesticides, because they metabolize non-toxic compounds similar to HACs. However, breakdown of HACs by these organisms is often very slow because they are not adapted to grow on these human-made compounds. Our goal is to find ways to stimulate this activity in the environment to help facilitate removal of HACs at existing contaminated sites and prevent their release into the environment. In particular, we are interested in stimulating the activity of photosynthetic bacteria – microorganisms that can convert these toxic compounds into valuable commodities (e.g. biofuels) using energy from the sun. The added advantage is that these organisms are found in almost all freshwater environments, can remove carbon dioxide from the atmosphere, and are not harmful to human health.

We work with a photosynthetic bacterium, Rhodopseudomonas palustris (Rpal). Rpal is commonly found in wastewater lagoons and has the ability to breakdown HACs. Rpal does this slowly, but Rpal exposed to HACs for a few months can quickly breakdown HACs. We will determine why Rpal adapted to HACs can breakdown HACs better than unadapted Rpal. This will uncover ways to stimulate breakdown of HACs by photosynthetic organisms in the environment.

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?

This project will lay the groundwork for development of new approaches and technologies to reduce the release of HACs, such as PCBs and pesticides, and remediate existing sites contaminated with HACs. These approaches will focus on stimulating the activity of native photosynthetic bacteria to breakdown these compounds. This work will also provide preliminary data on the feasibility of using photosynthetic bacteria in bioreactors fed with wastewater contaminated with HACs to recover valuable commodities such as fuels in addition to producing cleaner water.

Activities and Milestones

Activity 1: Activity 1. Determine why Rpal adapted to HACs are better at degrading HACs than unadapted Rpal.

Activity Budget: $87,057

Activity Description:
Rpal can degrade 3-chlorobenzoate, a product of PCBs; TCP, a herbicide contaminating the Great Lakes; and it has the potential to degrade other HACs. From work done with 3-chlorobenzoate and TCP, we know Rpal is unable to degrade these HACs until after it has been exposed to them for a few months, after which it becomes adapted to HACs and quickly degrades them. We know these adapted strains are different because if we expose them to more HAC, they immediately start to breakdown the HAC. Since the DNA inside of the bacterium acts as the "instruction book" for the bacterium, we will sequence the DNA in the adapted strains to determine if the "instructions" have changed in the adapted strains. This will tell us what the barrier is to degrading HACs immediately and how we can overcome this barrier.

Rpal also can use energy from light to breakdown HACs and produce biofuels like hydrogen. One potential outcome from this project is development of technology using Rpal as a biocatalyst to breakdown HACs and produce hydrogen as a fuel source. To determine the feasibility of this technology, we will measure how much hydrogen the adapted strains produces while degrading HACs.

Activity Milestones:

Description	Completion Date
Determine how Rpal strains adapted to HACs are different from unadapted Rpal	2022-04-30
Determine hydrogen production rates of adapted Rpal strains when degrading HACs	2022-06-30

Activity 2: Activity 2. Determine parameters to stimulate degradation of HACs by Rpal.

Activity Budget: $83,943

Activity Description:
Since Rpal and photosynthetic bacteria like it are commonly found in freshwater environments and water sanitation facilities exposed to sunlight, we want to determine how we can stimulate HAC degradation in Rpal so we can potentially stimulate the ability of photosynthetic bacteria like Rpal to degrade HACs in the environment. Preliminary studies suggest that addition of non-toxic aromatic compounds help stimulate degradation of HACs in Rpal that has never been exposed to HACs. The amount of available light and oxygen is also likely to affect degradation of HACs, since these parameters impact the amount of energy Rpal has to degrade HACs. Rpal consumes the greenhouse gas, carbon dioxide, while growing on HACs, so access to carbon dioxide could stimulate this activity. We will carry out a full evaluation of how each of these parameters (addition of aromatic compounds, light, oxygen, and carbon dioxide) affect the ability of Rpal to degrade HACs. This would allow us to determine how we can stimulate activity of photosynthetic organisms like Rpal in low-cost systems like wastewater lagoons. We will also test how these parameters affect hydrogen production rates of Rpal growing on HACs.

Activity Milestones:

Description	Completion Date
Determine how these parameters affect hydrogen production rates during HAC degradation	2023-06-30

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?

These results will also provide the necessary data to determine the feasibility of our approach and enlist the help of partners that can assist in implementing larger-scale testing as well as expertise in carrying out cost-benefit analysis. We envision these partners to potentially include other groups at the University, consulting groups, and agencies such as the Metropolitan Council Environmental Services and the Minnesota Pollution Control Agency. These results will also form the basis of a proposal to obtain federal funding to understand how photosynthetic bacteria can degrade HACs and its effect on the physiology of these organisms in more detail.

Project Manager and Organization Qualifications

Project Manager Name: Kathryn Fixen

Job Title: Assistant professor

Provide description of the project manager's qualifications to manage the proposed project.

Dr. Fixen is an assistant professor in the Department of Plant and Microbial Biology based on the St. Paul campus of the University of Minnesota. Dr. Fixen received her B.S. in microbiology at the University of Minnesota, her Ph.D. from Harvard University, and trained as a postdoctoral fellow at the University of Washington in Seattle, WA. Dr. Fixen has worked with photosynthetic bacteria for 10 years, and in that time she has published 11 research articles focused on understanding how these organisms work and getting them to work for us. Her work has been featured in Scientific America and Nature Microbiology.

Organization: U of MN - College of Biological Sciences

Organization Description:

The University of Minnesota is one of the largest and most prestigious public institutions in the country. In particular, the mission of the College of Biological Sciences is to "promote collaborative research within and beyond the University to advance knowledge and find solutions that improve human health and the environment locally, nationally and globally" (https://cbs.umn.edu/about/CBS). The Fixen lab located on the campus of the University of Minnesota-Twin Cities contains all of the necessary equipment and has access to core facilities that are required to carry out the proposed work.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Assistant professor		PI			36.5%	0.1		$11,910
Postdoctoral fellow		The postdoc will carry out the proposed experiments to adapt a photosynthetic bacterium to halogenated aromatic compounds, prepare samples for genome sequencing, test parameters to improve activity of this strain, and carry out data analysis.			25.4%	2		$123,276
Undergraduate research assistant		The undergraduate researcher will assist the postdoctoral fellow with a variety tasks to carry out experiments and maintain bacterial strains.			0%	0.1		$2,000
							Sub Total	**$137,186**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Tools and Supplies	Laboratory supplies, services, and analytical costs that include chemicals for all analyses, consumable plasticware, supplies to maintain analytical equipment, supplies for growth and maintence of bacterium, supplies for lab-scale bioreactor system, analytical fees, computational licenses, DNA purification kit and DNA sequencing).	These are all required and standard costs for the proposed experiments.					$33,814
							Sub Total	**$33,814**
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								
							Sub Total	**-**
							Grand Total	**$171,000**

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				
In-Kind	University of Minnesota	Because the project is overhead-free, laboratory space, electricity, and other overhead costs are provided in kind. The University of Minnesota overhead rate is 55% (equivalent to $94,050).	Potential	$94,050
			Non State Sub Total	**$94,050**
			Funds Total	**$94,050**

Attachments

Required Attachments

Visual Component

File: 581cb4ca-305.pdf

Alternate Text for Visual Component

This figure shows how a photosynthetic bacterium, Rpal, can convert toxic, halogenated compounds like PCBs and some pesticides into valuable commodities like biofuels. These bacteria are found in all freshwater environments, and we will determine how to stimulate photosynthetic bacteria to degrade toxic, halogenated compounds (HACs) in low-cost systems such as wastewater lagoons. We will also look at the feasibility of using Rpal to turn HACs into biofuels using photosynthetic bioreactors in a lab setting.

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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

No

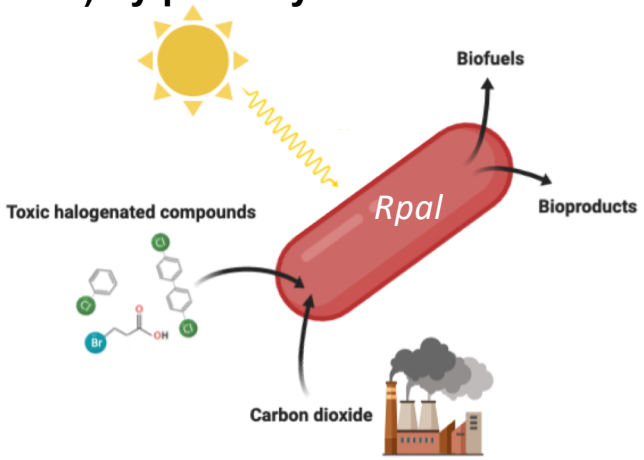
Does your project include research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

Degradation of halogenated compounds (PCBs, pesticides, etc.) by photosynthetic bacterium

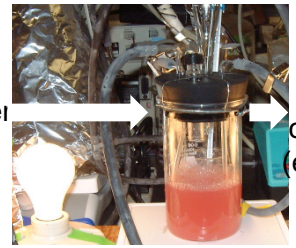


Advantages

- uses bacterium found in all freshwater environments
- low energy input and carbon neutral
- can operate in low light
- not harmful to human health

Water treatment and biofuel/bioproduct production

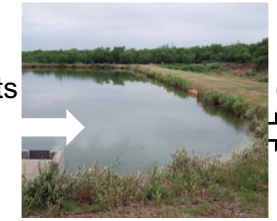
Wastewater in



valuable commodities (e.g. biofuels)

Non-toxic amendments to stimulate activity in environment

Amendments in



clean water out

Outcomes

- new technology to reduce release of halogenated aromatic compounds (HACs) and remediate existing sites contaminated with HACs
- production of valuable commodities using energy from light