Environment and Natural Resources Trust Fund
2020 Request for Proposals (RFP)

Project Title: **ENRTF ID: 078-B**

Bacterial Starvation for Improved Toxic Contaminant Treatment

Category: B. Water Resources

Sub-Category:

Total Project Budget: $ 235,854

Proposed Project Time Period for the Funding Requested: June 30, 2023 (3 yrs)

Summary:

We will understand how starvation changes bacterial function, resulting in their more extensive biodegradation of a greater number of contaminants of emerging concern, leading to development of simple treatment systems.

Name: Paige Novak

Sponsoring Organization: U of MN

Job Title:

Department: Department of Civil, Environmental, and Geo- Engineering

Address: 122 Civil Engineering Building, 500 Pillsbury Drive SE
Minneapolis MN 55455

Telephone Number: (651) 808-0859

Email novak010@umn.edu

Web Address:

Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

The visual shows how bacteria that are starved will consume a greater number of contaminants of emerging concern, such as pharmaceuticals, hormones, and industrial chemicals, and to a greater degree.

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

_____ Extent of Impact _____ Innovation _____ Scientific/Tech Basis _____ Urgency

_____ Capacity Readiness _____ Leverage _______ TOTAL _____%

PROJECT TITLE: BACTERIAL STARVATION FOR IMPROVED TOXIC CONTAMINANT TREATMENT

I. PROJECT STATEMENT

Our goal is to understand how a lack of "food" changes bacterial communities and their function, resulting in their biodegradation of a diversity of contaminants of emerging concern as well as biodegradation of these contaminants to lower concentrations. This will lead to the development of simple treatment systems for drinking water, surface water, and wastewater, resulting in water quality benefits for all of Minnesota.

Contaminants of emerging concern (CECs) include compounds such as natural and synthetic hormones, pharmaceuticals/personal care products, perfluorinated compounds, flame retardants, and a range of industrial products and byproducts. The presence of CECs in water can cause developmental and reproductive problems in fish and other biota. Human exposure to CECs has been linked to health impacts ranging from cancer to developmental problems.

Bacteria can biodegrade many CECs. Nevertheless, this biodegradation varies, is not well understood, and has not been systematically studied in a way that enables the development of simple treatment systems to reliably remove CECs from a range of impacted waters, including drinking water, surface water, and wastewater.

Research has shown that when bacteria are "starved" for food, they will adapt by consuming a much larger variety of food sources and consuming them to much lower residual concentrations--essentially, "eating everything on their plate" while simultaneously "cleaning their plate." We have studied this phenomenon with a general community of wastewater bacteria degrading a hormone. Other researchers have studied this phenomenon with pure cultures of bacteria in the laboratory degrading a range of harmless compounds, such as sugars. No one, however, has studied this phenomenon with a range of CECs and in a way that will enable the development of treatment systems. Our goal is to do just that.

To accomplish this goal, we will focus on common communities of bacteria that are known to be able to biodegrade a wide variety of compounds, including CECs, so-called iron-reducing bacteria. We will grow these bacteria under conditions of ample food supply and under starvation conditions.
We will then:

- Compare their ability to biodegrade a range of different CECs, including a common flame retardant, antibiotics, hormones, common pharmaceuticals, and perfluorooctanesulfonic acid (PFOS),
- Determine how the starvation impacts the residual concentration of these CECs after biodegradation, and
- Determine the point at which this phenomenon develops--essentially, how "hungry" must the organisms be to change their function in this manner?

Together, this will provide the needed information, particularly the last point, to develop treatment systems to stimulate this useful starvation response for the treatment of drinking water, surface water, and wastewater, resulting in water quality benefits for all of Minnesota.

II. PROJECT ACTIVITIES AND OUTCOMES

ACTIVITY 1: Determine how bacteria grown with abundant versus limited food sources differ in their ability (both in terms of rate and extent) to biodegrade CECs.

Description: We will develop communities of iron-reducing bacteria in continuously-fed reactors fed either an abundance of food (*e.g*., organic carbon, 500 mg/L) or maintained under starvation conditions (1 mg/L organic carbon). The communities will be amended with a mixture of 10 CECs representing a range of compounds of interest, including a common flame retardant, antibiotics, hormones, common pharmaceuticals, and perfluorooctanesulfonic acid (PFOS). The concentration of these CECs in the effluent will be measured over time to determine how many of the CECs are biodegraded under the different conditions and to what residual concentration.

ENRTF BUDGET: $138,192

Outcome	**Completion Date**
1. Development of communities of iron-reducing bacteria under conditions of abundant vs. limiting food sources.	*01/31/21*
2. Determination of how many CECs are biodegraded, and to what residual concentration, when amended to the two different types of communities (starved versus grown with abundant food).	*01/31/22*
3. Determination of how this behavior changes with longer exposure to conditions of starvation vs. abundant food.	*05/31/23*

ACTIVITY 2: Determine the "starvation threshold" at which bacteria develop an ability to biodegrade more CECs and to a lower concentration.
Description: Using the microbial communities grown under starvation conditions in Activity 1, multiple reactors will be started and fed organic carbon concentrations ranging from 10 mg/L to 10 µg/L. After the communities are stable in overall bacterial numbers, the reactors will be amended with the mixture of 10 CECs and their concentrations in the effluent will be measured over time to determine how many of the CECs are biodegraded under the different conditions and to what residual concentration.

ENRTF BUDGET: $97,662

Outcome	**Completion Date**
1. Development of communities of iron-reducing bacteria under a range of starvation conditions.	*06/31/22*
2. Determination of how, under starvation conditions, the concentration of "food" changes the number of CECs that are biodegraded, and to what residual concentration.	*04/30/23*

III. PROJECT PARTNERS AND COLLABORATORS:
Our primary project partners are the consulting firm Geosyntec and Metropolitan Council Environmental Services. We plan to provide updates to our partners during the project and work with them at the conclusion of the project to ensure that our results are widely disseminated via open lectures and discussion sessions to interested professionals, including those at relevant state agencies.

IV. LONG-TERM IMPLEMENTATION AND FUNDING:
I plan to submit a proposal to the National Science Foundation to further study this phenomenon, in terms of the actual physiological changes that occur in bacteria under conditions of starvation. This research complements other work currently being pursued in my laboratory on the effect of low carbon concentrations on the dominant mechanisms used by bacteria to biologically dechlorinate toxic industrial chemicals at contaminated sites. This research is also an extension of previous research that I performed on the effect of carbon/"food" on the biodegradation of the powerful human hormone estrone in wastewater.

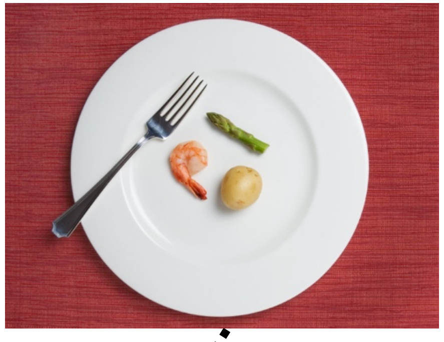
Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Paige Novak
Project Title: BACTERIAL STARVATION FOR IMPROVED TOXIC CONTAMINANT TREATMENT
Organization: University of Minnesota
Project Budget: $235,854
Project Length and Completion Date: 3 years, June 30, 2023
Today's Date: April 11, 2019

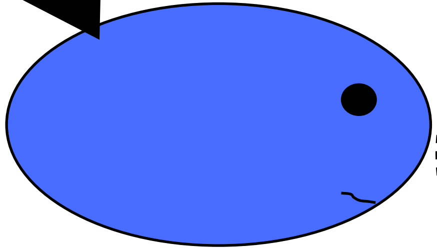
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 200,354	$ -	$ 200,354
Novak, PI (6% time per year for three years, salary 74% of cost, fringe benefits 26% of cost). Overall project supervision, experimental design, data analysis and interpretation.. Total estimated cost is $51,513.			
One Graduate Research Assistant (50% FTE per year for three years, salary 58% of cost, fringe benefits 10% of cost, tuition 32% of cost). Will grow iron-reducing bacteria, set up the flow-through reactors, perform the experiments described to determine how low concentrations of substrate enable better contaminant of emerging concern degradation, and will analyze samples and data. Total estimated cost is $148,841.			
Equipment/Tools/Supplies			
Laboratory supplies, services, and analytical costs (includes, but is not limited to, chemicals for all analyses, supplies to maintain analytical equipment, supplies for reactor construction, including pilot reactor construction, pumps for lab- and pilot-scale systems, monitoring equipment for pilot-scale systems, controllers for pilot-scale systems, gas extraction membranes, microbial analysis costs, analytical fees). These are all required and standard costs.	$ 35,500	$ -	$ 35,500
COLUMN TOTAL	$ 235,854	$ -	$ 235,854

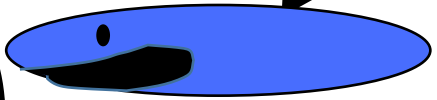
SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State: None		$ -	$ -	$ -
State: None		$ -	$ -	$ -
In kind: Because the project is overhead-free, laboratory space, electricity, and other overhead costs are provided in kind. The University of Minnesota overhead rate is 54% (equivalent to $101,457).	Estimated	$ -	$ -	$ -
Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	**Amount legally obligated but not yet spent**	**Budget**	**Spent**	**Balance**
Active: M.L. 2017, Chp. 96, Sec. 2, Subd. 04b		$ 450,000	$ 208,594	$ 241,406
Completed: M.L. 2014, Chp. 226, Sec. 2, Subd. 03d; M.L. 2017, Chapter 96, Section 2, Subdivision 18		$ 500,000	$ 454,288	$ 45,712
Completed: M.L. 2014, Chp. 226, Sec. 2, Subd. 03b		$ 279,000	$ 277,935	$ 1,065

Bacterial starvation leads to survival instincts, triggering degradation of a greater number of contaminants of emerging concern to a lower residual concentration.

We will understand this response so that we can trigger it for water treatment.







Limited degradation

Extensive degradation

Project Manager Qualifications and Organization Description

Paige J. Novak
Professor and Joseph T. and Rose S. Ling Chair of Environmental Engineering, Department of Civil, Environmental, and Geo- Engineering, University of Minnesota

B.S., Chemical Engineering, 1992, The University of Virginia, Charlottesville, VA.
M.S., Environmental Engineering, 1994, The University of Iowa, Iowa City, IA.
Ph.D., Environmental Engineering, 1997, The University of Iowa, Iowa City, IA.

Dr. Paige Novak will be responsible for overall project coordination. She has been studying the biological treatment of water and wastewater for over 20 years. Recent work has focused on the generation of energy from high-strength wastewater and the degradation of pollutants in wastewater and surface water. She has completed several LCCMR projects on understanding and enhancing the biodegradation of contaminants of emerging concern, as well as completing projects on understanding and enhancing the biodegradation of other toxic contaminants, supported by National governmental funding.

Organization Description
The University of Minnesota is one of the largest, most comprehensive, and most prestigious public universities in the United States (http://www1.umn.edu/twincities/01_about.php). The laboratory and office of the PI contains all of the necessary fixed and moveable equipment and facilities needed for the proposed study.