**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**

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| **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 willdevelop 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* | |

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| **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.