**PROJECT TITLE: An engineered solution to toxic copper coatings for boats**

**I. PROJECT STATEMENT**

**Aquatic heavy metal pollution is a global problem that may pose a serious threat to human health and have adverse effects on aquatic environments. A major source of metal pollution is copper-rich coatings. These coatings are used worldwide and in Minnesota to prevent biofouling, the natural process by which aquatic organisms attach to boats, docks, and anchors. It is our goal to replace toxic coatings, and prevent the damage they cause, by developing a new and biologically advanced generation of coatings. These coatings will significantly reduce the heavy metal pollution in Minnesota waterways.**

Heavy metals are a very potent source of aquatic pollution. Heavy metal pollution originates from mining, but also from other industrial uses such as metal-containing coatings. Heavy metals represent serious environmental and health threats as they can accumulate in the environment (e.g. in the sediments) but also in living organisms (e.g. in fat tissues). Even metals that are essential micronutrients such as copper, iron or zinc, are extremely poisonous when in excess. At the same time, chronic low exposures to metals have serious effects in the long run, affecting primarily the embryonic and larval stages, as demonstrated by studies on rainbow trout and the toxicity of 24-hour exposure to a low concentration of copper. If contaminated water is not properly treated, then these metals cause risks such as bioaccumulation that may prevent the safe consumption of commercial and recreational fish.

One use of heavy metals is in antifouling coatings. These coatings are for the prevention of biofouling, the spontaneous process by which aquatic organisms (e.g. bacteria, diatoms, algae, protozoan, sponges, mussels) colonize on the surface of submerged objects. To prevent biofouling, these coatings contain biocidal compounds to kill bacteria. The antifouling coating market is enormous: nearly $9 billion in 2018 and growing 8% a year. About 85% of this market is copper-based coatings, formulated with up to 40% (weight/weight) copper oxides.

Regulations against these metal-containing coatings, and in particular those containing copper, are getting harsher both in Europe and in the US because of the highly toxic nature of the metals and the fact that they spontaneously leach out of these coatings [https://echa.europa.eu/fr/information-on-chemicals/biocidal-active-substances; Washington Senate Bill 5436, Recreational Water Vessels--Antifouling Paints; 2011; California Senate Bill 623, Vessels: Marine Antifouling Paint; 2011]. **In fact, the U.S Congress approved banning the sale and use of copper-containing coatings in 2011, which has been pushed back to Jan 1, 2021 due to the lack of suitable alternatives.** **Copper-containing coatings are a major cause of contamination in recreational waters such as harbors, marinas, and lakes. Therefore, new strategies are needed to replace these toxic coatings in Minnesota.**

**We propose developing a highly innovative, ecologically safe antifouling coating** that will prevent the adhesion of aquatic macroorganisms to solid surfaces. To achieve this goal, we will take advantage of our recent discovery of 100% biological and eco-friendly molecules that make surfaces less adhesive to aquatic species. Our initial pilot and field testing experiments on Lake Superior, in the Duluth-Superior Harbor (DSH), confirmed that coatings containing these eco-friendly molecules were not fouled by aquatic organisms. In addition, our compounds were found to outperform other widely used molecules in coatings.

**II. PROJECT ACTIVITIES AND OUTCOMES**

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| **Activity 1:**Optimize the ecological antifouling coatings | **ENRTF Budget: 170,000$** |

We will optimize our coating formulation to improve the efficacy, stability, and durability of these coatings in aquatic environments. Experiments and tests will be performed at the University of Minnesota using water from the DSH and inland lakes to develop coatings that will later be field tested. Our goal is to make coating formulations containing our enzymatic biofouling inhibitors that are as durable as the best coatings currently available on the market.

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| **Outcome**  | **Completion Date** |
| 1. Improve the coating antifouling properties | November 1, 2020 |
| 2. Improve the coating durability | April 30, 2021 |

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| **Activity 2:**Conduct field experiments in the Duluth-Superior Harbor (DSH).  | **ENRTF BUDGET: 238,000$** |

In these field tests, we will perform a head-to-head comparative test of our ecological coating and the highest performance coatings on the market by measuring the adhesion of biofouling species like algae and invasive species such as zebra mussels to these coated surfaces. Sample coupons (steel, fiberglass) will be taken out of the harbor and analyzed after 1, 2, 5, and 12 months of exposure.

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| **Outcome**  | **Completion Date** |
| 1. Sample preparation and installation in the harbor |  July 30, 2021 |
| 2. Sampling and analysis of the samples. | June 30, 2022 |

**III. PROJECT PARTNERS:**

**A. Project Team/Partners**

The project will be carried out by a strong team that covers complementary areas. Collectively, our team’s expertise covers biochemistry, aquatic biology, environmental sciences, and engineering. The team consists of a Biochemistry Assistant Professor, Mikael Elias, a Biology Professor, Randall Hicks, and an engineering postdoctoral investigator. Dr. Elias discovered the biofouling inhibitory molecule, while Dr. Hicks has extensive expertise in microbiological processes underlining biofouling, and has performed field experiments in the DSH for many years. In collaboration with key strategic stakeholders in the field, including the Duluth Seaway Port Authority and a Minnesota company (AMI Consulting Engineers), our group has a unique collection of skills, expertise, knowledge and contacts to develop the coatings, perform the field testing, and collect the data that are necessary to transfer this technology to the market.

**A. Partners receiving ENRTF funding**

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| **Name** | **Title** | **Affiliation** | **Role** |
| Mikael Elias | Assistant Professor, PhD | University of Minnesota | Principal Investigator |
| Randal Hicks | Professor, PhD | University of Minnesota | Co-investigator |

**IV. LONG-TERM- IMPLEMENTATION AND FUNDING:**

Our initial pilot and field testing experiments on Lake Superior, in the Duluth-Superior Harbor (DSH), confirmed that our coatings containing these eco-friendly molecules were not fouled by aquatic macroorganisms, and outperformed existing coatings. We now propose to take advantage of our competitive advantage (i.e., novel, potent, patent protected biofouling inhibitor) to refine these coatings and investigate their properties and performance during a longer field study in real conditions. This innovative project may lead to a viable solution that limits heavy metal pollution not only in Minnesota but worldwide. This type of technological breakthrough is essential to help preserve aquatic environments in Minnesota, as well as reduce risks to human health. We and other firms and stakeholders we have contacted feel that the future potential of this innovative technology is enormous.

**V. TIME LINE REQUIREMENTS:** This project will take 24 months to carry out as described above. Thereafter, it is expected that the products of the project to be handed off to state agencies and the private sector.