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MnDRIVE-funded iGEM team turns mercury into gold

Undergraduate team takes home two honors from international competition

by Sarah Perdue

The iGEM – International Genetically Engineered Machines – competition challenges undergraduate students to identify real-world problems and solve them through biological engineering and design. Not only did the University of Minnesota's team exceed the requirements for a Gold Medal award at the 10th annual competition, held in Boston, MA October 30-Nov 3, they also were awarded Best Environment project. And if that were not enough, they also filed with the University's Office of Technology Commercialization (OTC) to begin the process of patenting part of their project.

Focusing on the bioremediation of the heavy metal mercury from contaminated water, team "Mntallica" pulled students from microbiology, chemistry, engineering and business. The team of undergraduates spent four months over the summer creating a methyl mercury-detoxifying bacterial strain and an improved water filtration device. Their work was partially funded by MnDRIVE, under the section: Advancing Industry, Conserving the Environment.

"The students have designed a clever way to rid the environment of toxic mercury compounds," says MnDRIVE co-director Sadowsky. "Their project meshes very nicely with the overall Bioremediation goals of our MnDRIVE initiative.

"We were really completing a holistic project," said team member Jessica Tarnowski, a senior genetics, cell biology and development major.

Tarnowski said the team became interested in the project while researching concerns about mercury contamination in the state's waterways, particularly in heavy mining areas. "High levels of mercury in the bloodstream can cause detrimental developmental disorders because it is a bioaccumulative neurotoxin," she said. She added that many newborns in parts of Minnesota and around the world have mercury levels well above accepted thresholds.

The team's first step was to engineer a bacterium that could pull mercury-containing compounds from the water and also survive in high concentrations of the toxic chemicals. The team started with the lab rat of microbiology – E. coli – and added these features through genetic engineering.

According to Stephen Heinsch, also a senior genetics, cell biology and development major, mercury contamination in water appears in two forms—methyl mercury and mercury ions. The team first introduced genes for transporter proteins that allowed the contaminating mercury compounds to enter the bacteria. Then they introduced genes that encode for proteins, named MerA and MerB, to convert the water-soluble mercury into a recoverable form.

"Once methyl mercury or mercury ions are inside, MerA and MerB proteins convert them into volatile mercury which then escapes the cell in the gaseous state," Heinsch said. The team was able to show that their engineered strain removed methyl mercury from the growth medium in test cultures in collaboration with Prof. Ed Nater's group in the Department of Soil, Water & Climate.

Heinsch was quick to note that converting mercury compounds in the water to gaseous mercury in the air is not the final solution. "We didn't want to make it someone else's problem," he said.

Enter the chemistry and engineering aspects of the project.

The team designed and fabricated a water filtration device to house the modified bacteria. Importantly, the team also encapsulated the bacteria in a silica gel to prevent their escape from the device, which also contains a filter that traps the volatilized mercury.

"The most important thing for us was to make it compatible with modern water filtration systems, which means being able to have water flowing through and being actively treated by live bacteria," said Niko Le Mieux, a senior chemistry and physiology major.

The team consulted U of M faculty members Al Aksan and Larry Wackett, who had previously developed silica gel encapsulation for bioremediation purposes. Because the team needed live bacteria, they experimented with different conditions until they developed a new encapsulation procedure that retains cell viability. It is this method improvement for which the team filed with OTC.

The team's advisors included Prof. Jeffrey Gralnick and Prof. Casim Sarkar and graduate student Aunica Kane. Their work was also funded by the College of Biological Sciences, the BioTechnology Institute, and the College of Science and Engineering with additional support from the Office of Naval Research, Cargill, 3M and Ecolab.

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Duluth shipping wars: fighting bacteria with bacteria

UMD Biology Professor Randall Hicks receives MnDRIVE grant to slow dock corrosion

by Sarah Perdue

Steel structures in the Duluth-Superior Harbor (DSH) are rapidly corroding, and bacteria in the harbor water are thought to be the culprits. Randall Hicks, a professor of biology at UMD, thinks that bacteria are also the solution.

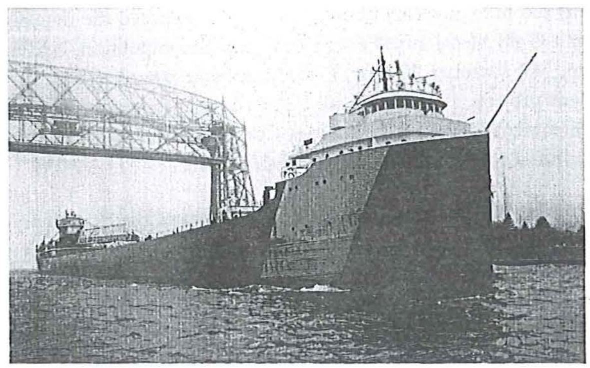
The busiest harbor in the Great Lakes region, the DSH contains over 20 kilometers of steel docks and bulkheads that are corroding at about twice the expected rate. Hicks' recent work suggests that the corrosion is due to bacteria in the harbor water that group together on the steel to form what is known as a biofilm. He received money from the MnDRIVE initiative Advancing industry, conserving the environment for a postdoctoral fellow to investigate methods of reducing the rate of steel corrosion in an environmentally-sustainable way.

"This is a big infrastructure problem," Hicks said, adding that the Duluth Seaway Port Authority recently estimated the cost to replace the damaged steel at around $200 million.

With the MnDRIVE award, Hicks was able to hire Simon Huang, an environmental engineering postdoc who joined the lab in September. "Our main goal is to explore whether there are ways that we can manipulate the microbial communities that appear to be causing or accelerating the corrosion of steel in the harbor," he said.

Hicks and Huang will take small "coupons" of the same steel used in the docks and subject them to different treatments before submerging them in samples of harbor water. They will then monitor corrosion rates and link those results to the composition of bacterial communities.

"Simon will see if we can use natural biochemicals, such as capsaicin from hot peppers, to disrupt the formation of these biofilm communities," Hicks said in describing one set of experiments. In other experiments, the researchers will pre-treat



the steel with species that are not implicated in corrosion to see if established bacteria can outcompete the harmful biofilm-associated species.

Another benefit of trying to alter the microbial communities that colonize the steel, as opposed to changing the coatings on the steel itself, is that bacteria can replicate. "In the spring, when ice in the harbor breaks up it can scar coatings and quite often we see this corrosion occurring at the scratches," Hicks said. "If we had something that was self-healing like a microbial community, that may be better."

Hicks credits the MnDRIVE funding for allowing his lab to begin investigating ways to reduce the corrosion rate. "Before [MnDRIVE] our work was mainly identifying how quickly this corrosion was occurring and who the bacterial player might be," he said. "Now we're at a point where we can potentially mitigate the problem by trying to manipulate the communities to see if that would be an effective means of reducing the initial stages of corrosion of new steel going into the harbor."

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Ammonia for Breakfast, Estrogen for Lunch

MnDRIVE researchers harness bacteria to boost micropollutant removal in high-efficiency wastewater treatment facilities.

by Sarah Perdue

Call it the Minnesota water cycle: fish live in lakes and streams, Minnesotans catch and eat fish, humans produce waste, bacteria in our wastewater treatment plants eat the human waste, and the purified water is discharged into the lakes and streams where fish live.

Though treatment plants remove wastewater pollutants to a large degree, the discharge of even very low levels of micropollutants, such as estrogen and other naturally produced human hormones, can significantly affect freshwater fish. University of Minnesota researchers are stepping up to the challenge of reducing the levels of micropollutants discharged to surface waters in the most cost- and energy efficient matter possible.

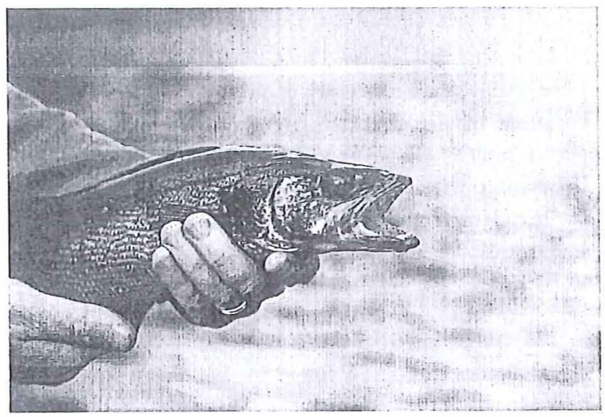
"The release of E1, a form of human estrogen, has the potential to change ecosystems and fish populations, and affect recreation," said David Tan, a postdoctoral fellow with Paige Novak, Professor of Civil, Environmental, and Geo-Engineering. Tan's fellowship is funded through MnDRIVE: Advancing Industry, Conserving Our Environment.

Current wastewater treatment technology is good at removing macropollutants, such as ammonia, by harnessing bacteria to convert toxic ammonia to nitrate. Tan said that the bacteria that remove E1 also happen to thrive under the same conditions as these ammonia-degrading bacteria.

However, systems that remove ammonia – and therefore E1 – in this way, are energy intensive.

"Removing micropollutants can be cost-prohibitive and comes with its own set of environmental impacts," Tan said. "The two big problems moving forward with wastewater treatment are energy efficiency and micropollutant removal."

Other researchers are currently developing more energy-efficient wastewater treatment systems to remove harmful nitrogen-containing compounds like ammonia, but their impact on E1 or other micropollutant removal is unknown. Tan and Novak expect their research will help strike a balance between energy-efficiency and the effective removal of micropollutants.



"We're planning to investigate these new wastewater treatment technologies and then evaluate them in terms of nitrogen and E1 removal," Tan said.

As a graduate student in Novak's lab, Tan worked on a MnDRIVE-funded project that evaluated how different wastewater operation strategies could lead to improved E1 removal. In a wastewater treatment system model in the lab, he altered the organic loading cycle and the concentration or type of the organic material and then measured E1 levels. Now, he and Novak plan to apply the conclusions of that work to the new wastewater treatment techniques.

"As utilities try to balance the opposing demands of energy efficiency, nitrogen removal, and micropollutant removal, we'd like to provide the very best information possible so that infrastructure improvements can be made to meet discharge regulations while also providing a decreased carbon and energy footprint and improved micropollutant removal," Novak said.

With the MnDRIVE funding, she and Tan hope to achieve just that.

Tan and Novak's work is also funded through the state's Legislative-Citizen Commission on Minnesota's Resources fund.

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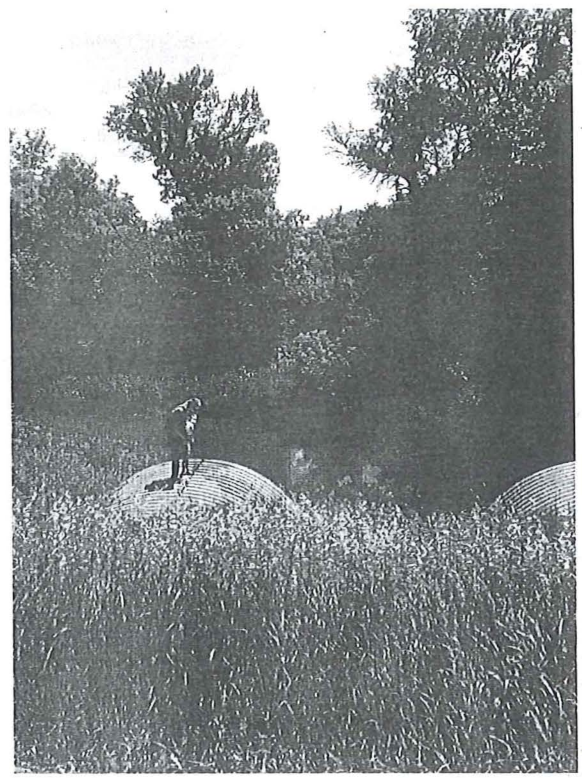
Muddy Waters

Conditions in Southern Minnesota streams have deteriorated, and UMN senior Katie Kemmitt hopes to find out why.

by Kelsey Dahlgren

"The purpose of my work is to study nutrient cycling and concentrations in streams in Southern Minnesota," says Kemmitt, a biology major working with Ecology, Evolution, and Behavior professor Jacques Finlay. Her goal is to identify the reasons for the deterioration, which leaves some streams smelly, turbid, and lacking biodiversity.



Funded by a MnDRIVE undergraduate fellowship, she travels to streams throughout southern Minnesota to collect water and sediment samples. Back in the lab, she analyzes the samples for nutrients such as nitrate, phosphorous, and carbon. Kemmitt hopes that her data will help determine the cause of the stream deterioration and assist in the development of tools to restore damaged streams and prevent further deterioration.

"Working on the Minnesota River Project has been the single most influential thing I've done as an undergrad," said Kemmitt. "I learned what I want to do with my life. I definitely want to work in water management and water resources."

Citing her research project in Dr. Finlay's lab as the major influence, Kemmitt will continue working in the lab through the summer and apply to graduate ecology programs this fall.

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