Researchers track the toxicity of Lake Erie cyanobacterial blooms

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Efforts to reduce the amount of phosphorus and other nutrients washing off farm fields and into Lake Erie shifted into overdrive after high levels of a bacterial toxin shut down the drinking water supply to more than 400,000 Toledo-area residents last August.

Nutrient levels help determine when and where rapid cyanobacterial buildups occur, as well as the size of those blooms. But what factors control their toxicity? The Great Lakes are home to dozens of common cyanobacterial species, but only a few are toxic troublemakers.

"We know what causes these blooms: It's nutrients from farm runoff. What we don't fully understand is what determines whether these cyanobacterial blooms are highly toxic or not," said University of Michigan marine microbiologist and oceanographer Gregory Dick, leader of a multidisciplinary project that applies state-of-the-art genomics and environmental chemistry techniques to the Lake Erie problem.

Dick said he hopes the study yields insights that can be incorporated into computer-based ecological models used to forecast cyanobacterial blooms.

"By applying innovative technologies to study these harmful algal blooms, we're opening new windows into what organisms are there and how those communities change over time," he said. "We're able to track specific organisms in a way that hasn't been possible before."

Dick's team was awarded a $250,000 grant from the U-M Water Center for an 18-month project that began May 1, 2014. Members of the team will present results from the 2014 field season next week during an international conference on cyanobacterial blooms at Bowling Green State University in Ohio. They will participate in a Monday evening poster session and a Wednesday workshop.

The U-M work relies heavily on the techniques of environmental genomics, which enable researchers to extract and sequence genetic material in water or soil samples and to piece together the genomes of the organisms present.

The project is expected to produce full DNA sequences for at least 50 Lake Erie microbes this year, Dick said. Thirteen genomes from laboratory-grown Great Lakes cyanobacterial strains have already been completed and will be used to aid in the interpretation of the environmental genomes.

"One of the unique elements of our study is that we tracked whole microbial communities in western Lake Erie for the entire season, so we'll be able to determine how the compositions change over time," Dick said. "No one else has looked at which microbial species are present at such a fine scale."

Last Aug. 4, the day the Toledo drinking-water restrictions were lifted, Dick's team conducted its regular Monday morning water-sampling trip to the city's water intake, one of six stations in their network. The U-M researchers piggybacked onto a monitoring and sampling effort led by the National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Laboratory in Ann Arbor.

Analysis of the Aug. 4 samples from the water intake revealed the presence of 12 species of cyanobacteria: five that are capable of producing microcystin toxins, three that cannot produce microcystins, and four unclassified organisms. The toxin-producing species included *Microcystis aeruginosa*, the cyanobacterium blamed for the Toledo crisis and by far the most common toxic cyanobacterium in western Lake Erie.

On July 29, just four days before high levels of microcystin shut down the Toledo water system Aug. 2, U-M aquatic geochemist Rose Cory and her co-workers also collected water samples from the six Lake Erie sites. But instead of microbes, they were looking for chemical substances suspected of playing a role in shaping the toxicity of cyanobacterial blooms.

One such chemical is hydrogen peroxide, the oxygen-containing compound commonly used as a disinfectant and found in countless home medicine chests. But the hydrogen peroxide Cory studies is naturally produced in Lake Erie—and in freshwater and marine systems worldwide—when the ultraviolet radiation in sunlight interacts with organic carbon particles dissolved in surface waters.

Hydrogen peroxide and other so-called reactive oxygen species can damage aquatic organisms through a process called oxidative stress. Previous research, including work by Hans Paerl of the University of North Carolina, suggests that the toxin microcystin helps protect cyanobacteria from oxidative stress.

Under conditions of high oxidative stress—during long summer days when abundant sunlight and warm water temperatures favor the conversion of organic carbon into hydrogen peroxide and other reactive oxygen species, for example—toxin-producing cyanobacteria appear to have a competitive advantage over their nontoxic cousins.

Intriguingly, Cory and her co-workers found that levels of hydrogen peroxide at the six western Lake Erie stations peaked July 29. On that date, levels were two to three times higher than what's typically found in lakes and other freshwater systems, though still far below levels that would be of concern for human health.

"There are very high concentrations of hydrogen peroxide in the surface waters of Lake Erie, levels that are high enough that—in controlled studies—they have detrimental effects on cyanobacteria and other organisms," said Cory, an assistant professor in the U-M Department of Earth and Environmental Sciences.

"The fact that the levels peaked when they did is tantalizing, but it doesn't prove any role for hydrogen peroxide. It doesn't mean that the toxin-forming algae are growing in number and blooming because they are better able to cope with hydrogen peroxide, for example. But these results provide some evidence for the hypothesis that hydrogen peroxide may be important."

To follow up on those findings, Cory and colleague Timothy Davis at the National Oceanic and Atmospheric Administration are conducting field and laboratory experiments. They add various amounts of hydrogen peroxide to Lake Erie water samples containing toxin-producing cyanobacteria, then measure microcystin production.

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