Active Early Detection and Diagnosis of HABs with Scalable Biological Treatment Strategies

Lead: Young Seo, University of Toledo, Youngwoo.Seo@UToledo.edu
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USACE Harmful Algal Bloom Research & Development Initiative

Delivering scalable freshwater HAB prevention, detection, and management technologies through collaboration, partnership, and cutting-edge science.

Problem

Early warning of cyanobacterial bloom occurrence and bloom condition is necessary to respond to harmful algal bloom (HAB) occurrences with appropriately targeted water treatment methods.

Objective

Advance molecularly informed, near real-time HAB diagnostics to support improved HAB monitoring and to optimize HAB treatment processes.

Approach

Develop cost-effective, field applicable technologies to mitigate HAB risks via (1) improved fluorometric sensors and identification of novel early warning biomarkers that monitor—in near real-time—the state (and treatment response) of HABs, (2) nature-inspired biological treatment methods for the removal of cyanobacteria and their toxins (e.g., cyanophages, environmentally friendly algaecides, and/or biofilters), and (3) the integration of these developed methods with currently applied HAB management processes.

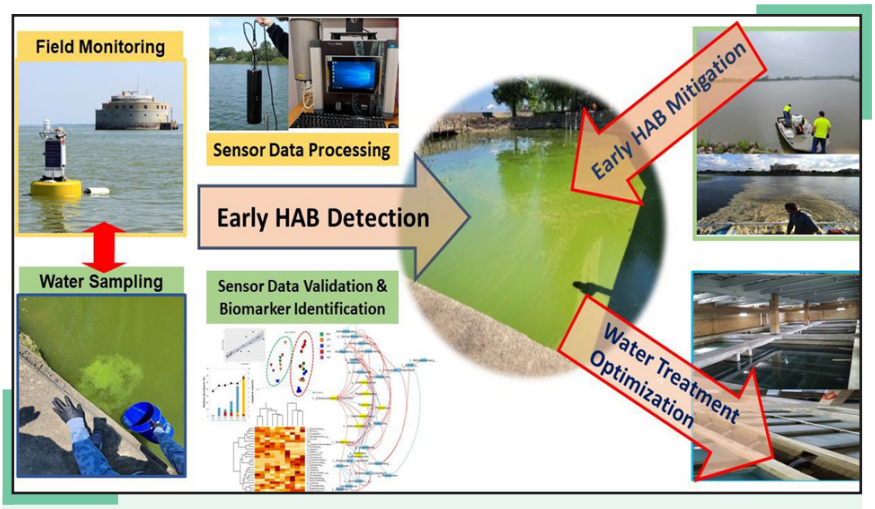

Figure 1. *Schematic diagram for the project goal.*

Results

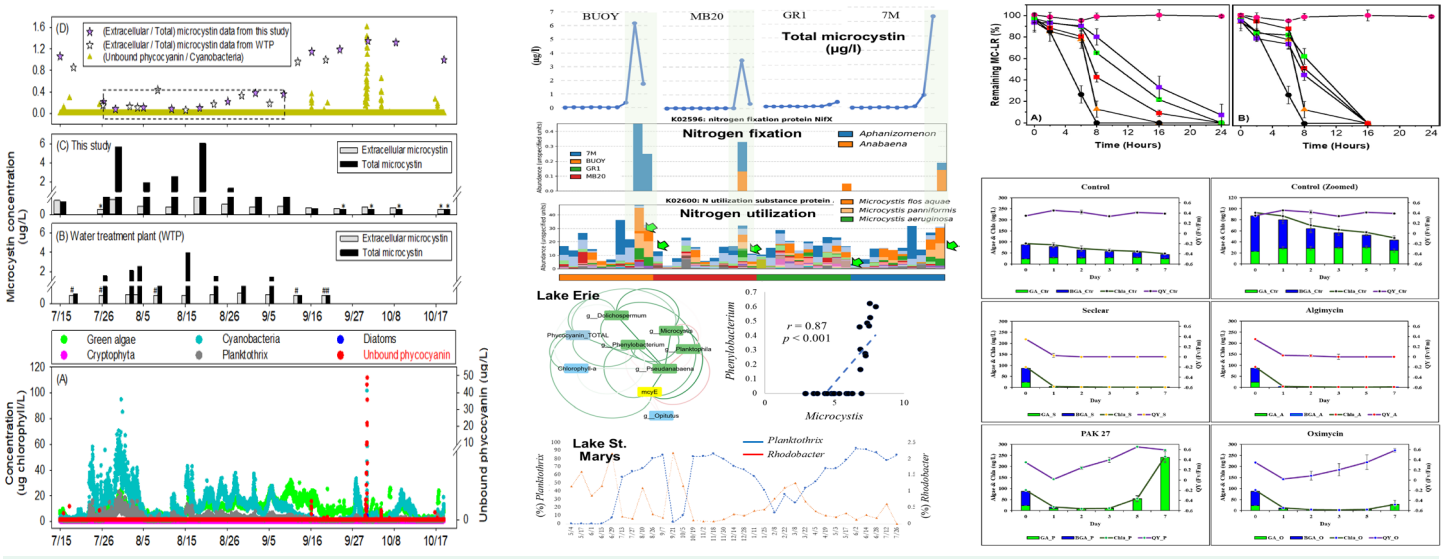

Figure 2. *Sample data displaying obtained outcomes of each objective: (left) unbound phycocyanin serves as an early indicator of HAB cell lysis and release of toxins into the environment, (middle) nitrogen metabolism plays a significant role on HABs both in Lake Erie and Lake St. Marys, and (right) biological and chemical treatments show their potentials to control cyanobacteria and their toxins.*

ENVIRONMENTAL LABORATORY
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Results (cont.)

Sampling was consistently conducted biweekly in both Lake Erie and Grand Lake St. Marys, Ohio. In Lake Erie, multiple additional sampling locations, including a low service water pump station, were included to improve the capture of microbial activity before, during, and after cyanoHABs. The study monitored physicochemical and pigments parameters to gain insights into cyanoHABs, and the levels of toxins were also measured using liquid chromatography with tandem mass spectrometry. To investigate microbial dynamics of cyanobacterial species and their neighboring community, amplicon sequencing (16S, 18S, and fungal internal transcribed spacer) was employed. The functional roles on cyanoHABs were investigated through metagenomic sequencing, targeting bacterial and viral DNA. Multiomic data were then aligned with qantitative polymerase chain reaction data (targeting cyanobacterial 16S, mcyE, and mlrA genes) and water parameter data to validate potential biomarkers for early warning of cyanoHABs. Additionally, a data-driven machine learning approach, combining sequencing and water physicochemical data, was considered to efficiently integrate rich multiomic and physicochemical data for the identification of early warning biomarkers.

Both lab and field tests (mesocosm tests at Lake Erie and full-scale field tests at a reservoir in Bowling Green, Ohio) were conducted for selected commercial algaecides. The influence of commercial algaecide treatment on cyanobacteria inactivation and the release of algal organic matter and toxins, as well as on microbial community responses were monitored. Additionally, the team explored new methods of controlling cyanobacteria by targeting carbon dioxide fixation and evaluating the efficacy of cyanophage treatment. They found that a combination of cyanophages and low-dose algaecide treatment was effective in controlling cyanobacteria blooms and that the lytic activity of cyanophages was enhanced with low-dose peroxide treatment. The team also constructed and tested lab-scale biofilters using cyanotoxin-degrading bacteria for removing microcystin-LR, which were found to be effective in removing microcystin-LR with reduced lag phage time for toxin biodegradation. Research findings of the project have been disseminated through peer-reviewed journal articles and presentations at national and international conferences. Based on the results of the first two years of the project, the team has published two peer-reviewed journal articles and presented their findings at 15 research conferences. The team also has one manuscript currently under review, and is preparing seven more manuscripts for submission.

Figure 2. *Algecide tests at a lake in Bowling Green, Ohio.*

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Major Milestones

Deliverable	Description
Publications	**Journal Articles:** Baranwal, P., D.-W. Kang, and Y. Seo. 2022. "Impact of Algal Organic Matter and Humic Substances on Microcystin-LR Removal and Their Biotransformation during Biodegradation." *Science of the Total Environment* 852:157993. https://doi.org/10.1016/j.scitotenv.2022.157993. Jeon, Y. P. Baranwal, L. Li, K. Piezer, and Y. Seo. 2022. "Review: Current Understanding on Biological Filtration for the Removal of Microcystins." *Chemosphere* 313:137160. https://doi.org/10.1016/j.chemosphere.2022.137160. In review. "Field and Laboratory Studies of Fluorescence-Based Early Warning Systems for Tracking Cyanobacterial Cell Lysis and Microcystins Release." *Water Research*. In review. "Inhibition of CO_2 Fixation in the Microcystis aeruginosa as a Potential Target for the Control of Freshwater Cyanobacterial Harmful Algal Blooms." *Environmental Science & Technology*. In prep. "Assessing Release of Intracellular Organic Matter from Cyanobacteria Following Application of Commercial Algaecides." *Journal of Hazardous Materials*. In prep. "Synergistic Impact of Combined Application of Cyanophage and Algaecide against Bloom Forming Cyanobacteria." *Harmful Algae*. In prep. "Metagenomic Insights into the Impact of Commercial Algaecides on Harmful phy-Toplankton and Microbial Community Responses: Mesocosm Study." *Water Research*. In prep. "Synergistic Role of Endogenous Multispecies Biofilms in Biological filters for Cyanotoxin Removal." *Water Research*. In prep. "An Insight into Microbial Community Dynamics and Interactions of the Persistent Planktothrix-Dominated Bloom in Grand Lake St. Marys." *Harmful Algae*. In prep. "A Metagenomic Approach to look into Lake Erie Cyanobacterial Harmful Algal Bloom, Quest for an Early Warning Biomarkers." *Water Research*.
Products	**Invention Disclosure.** Target specific inhibition and control of cyanobacteria and green algae. May 2023
Tech Transfer and Demonstrations	**Sensor system deployment and real time monitoring of water.** City of Toledo water treatment plant operators. July–October 2022 **Sensor system deployment and training.** City of Defiance water treatment plant operators. May 2023