

Guarding our water together: the silent threats and sustainable solutions of cyanotoxins monitoring in freshwater

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Cyanotoxins are the hidden dangers of freshwater lakes produced by cyanobacteria in warm and nutrient-rich environments, which are becoming more prevalent due to climate changes. The sophisticated monitoring methods of cyanotoxins, such as liquid chromatography-mass spectrometry, are usually time-consuming, complicated, and expensive. This is where innovative biosensors offer promising and sustainable solutions for cyanotoxins monitoring because they are portable, user-friendly, and cost-effective, which can quickly detect the presence of cyanotoxins. These “cyanotoxins detectives” use enzymes, antibodies, nucleic acids, and receptors to capture and produce signals in the presence of toxins. We conduct a compelling case study at a freshwater recreational lake, Taman Aman Lake, in Petaling Jaya, Malaysia. The lake is dominated by *Microcystis aeruginosa*, a cyanobacteria known for producing microcystins, and it exemplifies the need for accessible monitoring solutions. Thus, a sustainable toolkit, MicStrip™, an optical biosensor, is developed to provide on-site and continuous monitoring of cyanotoxin detection through simple colour changes. MicStrip™ transforms complex bioscience procedures into sustainable, accessible, community-driven solutions for protecting water ecosystems and public health. The key agenda for sustainable lake management shall involve community stewardship. By empowering the community as citizen scientists and educational outreach programs, the community can be the active guardian of freshwater resources.

Introduction

Imagine a perfect day with people by the lake having recreational activities such as jogging, fishing, and boating. However, something sinister is lurking beneath the lake's surface. It is not visible to the naked eye, but IT IS THERE!!! And known to be cyanotoxins. These dangerous toxins, produced by harmful algae blooms, can make the lake a health nightmare in just a day.

Due to climate changes, more and more recreational lakes have been dominated by these harmful algae blooms. These harmful algae blooms are known as cyanobacteria or blue-green algae. They can grow uncontrollably and form large blooms in lakes, ponds, and rivers when conditions are right—warm temperatures and nutrient-rich. Some types of cyanobacteria can even produce cyanotoxins, such as microcystins, anatoxins, nodularins, and cylindrospermopsin.

Exposure to cyanotoxins can cause many health problems. If you swim in or accidentally drink water contaminated with cyanotoxins, you could suffer from vomiting, headaches, or even long-term liver damage. These toxins do not just affect humans. They can also harm fish and other aquatic life. When fish ingest cyanotoxins, they can accumulate in the food chain, causing harm to animals and even humans who eat the fish.

But how do we know if the water is safe from cyanotoxins? This is where monitoring and guarding our lake waters is important. Scientists have been collecting water samples and sending them to labs for sophisticated analysis, such as liquid chromatography-mass spectrometry. This advanced technique can be laborious, time-consuming, expensive, and require specific training and scientific knowledge. Therefore, timely detection of cyanotoxins is challenging as many places still need more infrastructure for regular monitoring and reporting. First and foremost, do we need a team of

Table 1. The biochemical principles behind the signal production upon specific interaction of cyanotoxin and biological element

Biological elements	Biochemical processes
Enzymes	Produce measurable signals as detectable products through enzyme–substrate reactions. In this context, the target analyte is the substrate.
Antibodies	Antibody–antigen-specific binding based on immune interactions, which produces measurable signals.
Nucleic acids	Nucleic acids such as DNA and RNA can detect complementary sequences or analytes through hybridisation or aptamer-based binding and produce measurable signals.
Protein receptor	The analyte serves as a ligand that protein receptors can specifically recognise to produce measurable signals.

white-coated scientists to figure out water quality, or can ordinary folks roll up their sleeves and get the job done?

Sustainable solutions for cyanotoxins monitoring

Bioscience has come a long way, and new technologies could help us detect cyanotoxins much faster. Think of a biosensor—a small, portable, smart water detective that can instantly monitor cyanotoxins in a lake. A biosensor comprises a biological element that can specifically bind to a target analyte. Examples of biological elements are enzymes, antibodies, nucleic acids, and receptors—think

of them like nets to ‘catch’ the cyanotoxins. When these toxins are captured by the ‘nets’, they produce signals indicating their presence, with underlying biochemical reactions (Table 1). These signals are converted by a transducer to be measured in the form of electrical changes (electrochemical), colour changes (optical), heat changes (thermal), and mechanical vibrations (piezoelectric). These signals can be amplified and captured by a detector. So, the biosensor works like an alarm system.

The biosensor is small and portable so that it can be carried to water sites (Figure 1). It is also user-friendly and cost-effective. Additionally, biosensors can be used

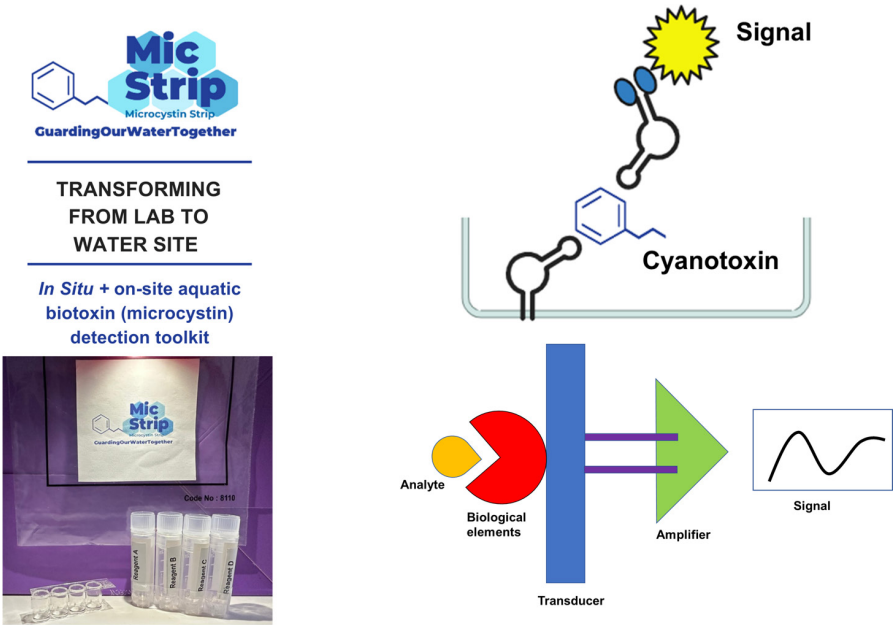


Figure 1. An *in situ* and on-site toolkit, MicStrip™, is developed for cyanotoxin monitoring with the tagline "transforming from lab to water site". It works based on the ability of oligonucleotide sequences to recognise the cyanotoxins' binding sites. The transducer in the biosensor converts the biological signal to an amplifiable output.

with automated systems for continuous monitoring. They are sustainable in a way that consumes minimal reagents and produces less waste. Thus, they are a more practical and eco-friendly solution for guarding the water quality and serve as efficient cyanotoxin-monitoring toolkits.

Case study: Taman Aman Lake

Let's look at Taman Aman Lake in Petaling Jaya, Malaysia, a former tin-mining pool transformed into a recreational lake for the public (Figure 2). The lake now faces significant algae bloom issues threatening its ecosystem and recreational values. It has poor water quality with an unusually high influx of nutrients that cause uncontrolled algae growth. Although this lake initially served as a water retention pond and is not meant for recreational and human activities, the lake's health must be taken seriously as the lake is located in the centre of a recreation park with a few residential areas nearby.

Microcystis aeruginosa, a colonial cyanobacteria, are identified by examining the lake water. This blue-green algae is unicellular (1–9 µm) and forms irregular or subspherical colonies. It is known to produce cyanotoxins, especially microcystins. As we learn about the existence of cyanobacteria, we are prompted to take immediate action to monitor the presence of cyanotoxins. At present, the monitoring of this lake is completed using LC-MS, which does not reach out to the community as a citizen stewardship effort.

Therefore, we develop an *in situ* and on-site cyanotoxins detection toolkit, known as MicStrip™, for rapid monitoring by local authorities and communities. MicStrip™ is an oligonucleotide-based optical biosensor

that produces colour changes if cyanotoxins are present significantly. MicStrip™ offers several advantages: it is portable for on-site use, easily observed with colour changes on the strip, user-friendly, no specialised equipment required, and timely monitoring. MicStrip™ transforms complex laboratory procedures into a simple on-site testing solution, enabling quick response time and proactive water management. By eliminating cost, expertise, and infrastructure barriers, MicStrip™ empowers local authorities to protect public health through timely detection and mitigation of water safety threats.

A user manual is included in the MicStrip™ to guide the community from sampling to testing and interpreting the results. MicStrip™ contains gloves, strips, solutions, and disposal bags manageable by the community. Most importantly, it only costs as low as your midday snack per toolkit. We will distribute the toolkit to environmental NGOs such as Water Warriors (<https://sustainability.um.edu.my/water-warriors-um>), Sekitar Kita (<https://sekitar.com.my/>), and Fuse Ecoteer (<https://www.fuze-ecoteer.com/>) for citizen scientists (Figure 3). The local municipal councils will also adopt the toolkit for sustainable environmental monitoring.

Way forward

Restoring and protecting recreational lakes requires immediate action with long-term sustainability, focusing on the timely monitoring of cyanotoxins. Any restoration efforts will rely heavily on the ongoing stewardship and vigilance of the local community in protecting this urban oasis. Community involvement is vital, and a strong consortium could be established as the

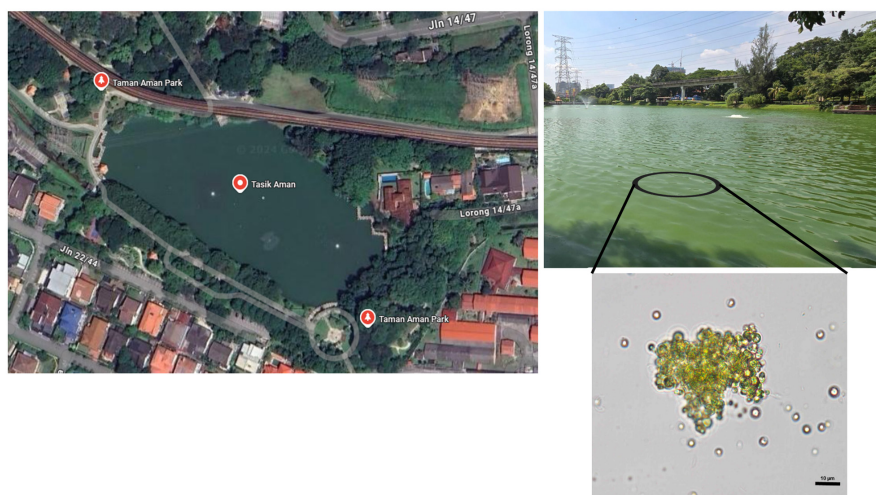


Figure 2. The satellite view of Taman Aman Lake at Petaling Jaya, Malaysia. Obviously, murky green algal blooms are consistently present on the water surface, which *Microcystis aeruginosa*, a colonial cyanobacteria, dominates.



Figure 3. The involvement of citizen scientists in their on-site activities at Taman Aman Lake, as seen from left to right, perform water quality testing using a multiparameter water quality meter, collecting water samples and labelling water samples.

scientific foundation for these initiatives. Empowering residents to become active stewards and guardian angels of their water resources by fostering citizen scientists and educational outreach can create a more informed and engaged community. Moving forward, sustainable

monitoring solutions of cyanotoxins at recreational lakes enhance the water management strategies as a replicable model for other water bodies with similar challenges. The goal is simple: guarding our water together for a better tomorrow. ■

Further reading

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