Blue-green algae: every lake is unique

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Topics: Biodiversity | Ecosystems

To predict toxic algal blooms, researchers from Eawag recommend a combination of species identification and chemical measurements. Now, a new study confirms that there is no magic formula and that, instead, specific indicator molecules are needed for each lake.

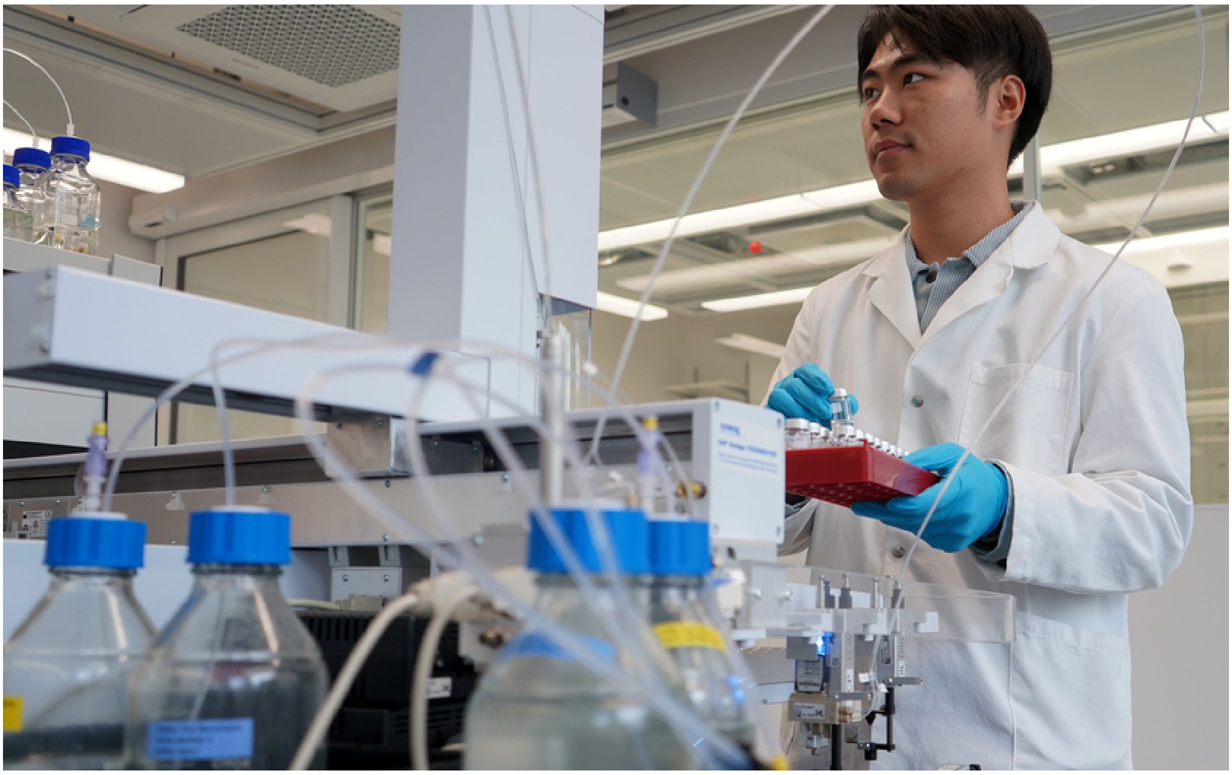
Cyanobacteria, also known as blue-green algae, can proliferate very rapidly in lakes in the warmer months of the year. Among the many species of cyanobacteria, there are some that produce toxins, and when such a toxic algal bloom occurs, the authorities have to be ready to act quickly and implement protective measures such as a bathing ban in the lake in question. The authorities are assisted in these efforts by monitoring programmes that measure biomolecules produced by the cyanobacteria. Until now, pigments such as chlorophyll have traditionally been used as indicators pointing to the growth of hazardous blue-green algae.

Now, however, researchers from the Swiss Federal Institute of Aquatic Science and Technology (Eawag) have demonstrated in a study that, in the case of Lake Greifensee, these pigments have almost no predictive capacity – as is the case for a number of other indicators suggested by the World Health Organization (WHO). Instead, from the whole cocktail of biomolecules that produce the cyanobacteria, the researchers picked out four that can be used to specifically monitor the formation of a toxic bloom – but only for Lake Greifensee. Indeed, there are major differences between individual lakes that have to do not only with the lakes' physical and ecological characteristics, but also with which cyanobacteria are prevalent in that body of water.

Cyanobacterial bloom of 2017 in Lake Greifensee (photo: René Schittli, Cantonal Laboratory Zurich).

Fishing in a toxic cocktail

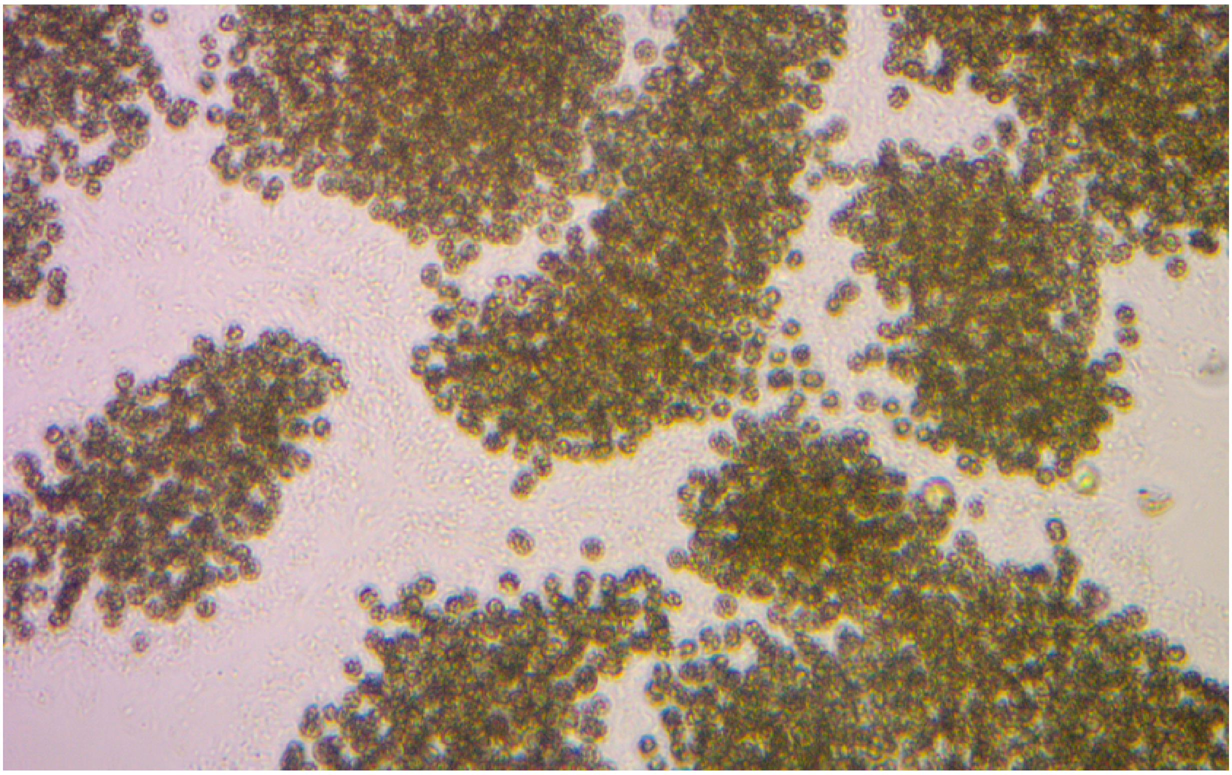
“Toxic blooms are a regular occurrence in Lake Erie in North America, for example, where chlorophyll works as an excellent indicator as long as the cyanobacteria are primarily responsible for the chlorophyll and the signal isn’t influenced by other algae. Unfortunately, things aren’t that straightforward in Lake Greifensee,” says environmental chemist Elisabeth Janssen. “In other words, there’s no magic formula and we instead recommend considering each lake separately”, adds her doctoral student and first author of the article Xuejian Wang.



Xuejian Wang, doctoral student in Eawag's Environmental Chemistry department, analyses cyanotoxins from Lake Greifen using a mass spectrometer (Photo: Eawag, Andri Bryner).

This observation will be familiar to experts from practical experience and is supported by ample evidence from the extensive Swiss National Science Foundation project, a collaboration between chemists, ecologists and microbiologists at Eawag. The recently published study reveals the annual fluctuations in a large number of biomolecules produced by cyanobacteria over a longer period of time (five years) than any previous publication. In total, 850 samples taken from Lake Greifensee between 2019 and 2023 were analysed, and 35 biomolecules were regularly detected.

By correlating the occurrence of various molecules with that of toxic blooms, the researchers provided clear evidence that pigments in Lake Greifensee are poorly suited to the targeted monitoring of toxic algal blooms. The Eawag team made a precise comparison between biomolecules in Lake Greifensee and in cyanobacteria isolated from the lake. They found that there are biomolecules that would have been well suited as indicators in some years but not in others depending on the dynamics of the various cyanobacteria in the lake, which can change slightly not only over the course of the year but also from year to year.

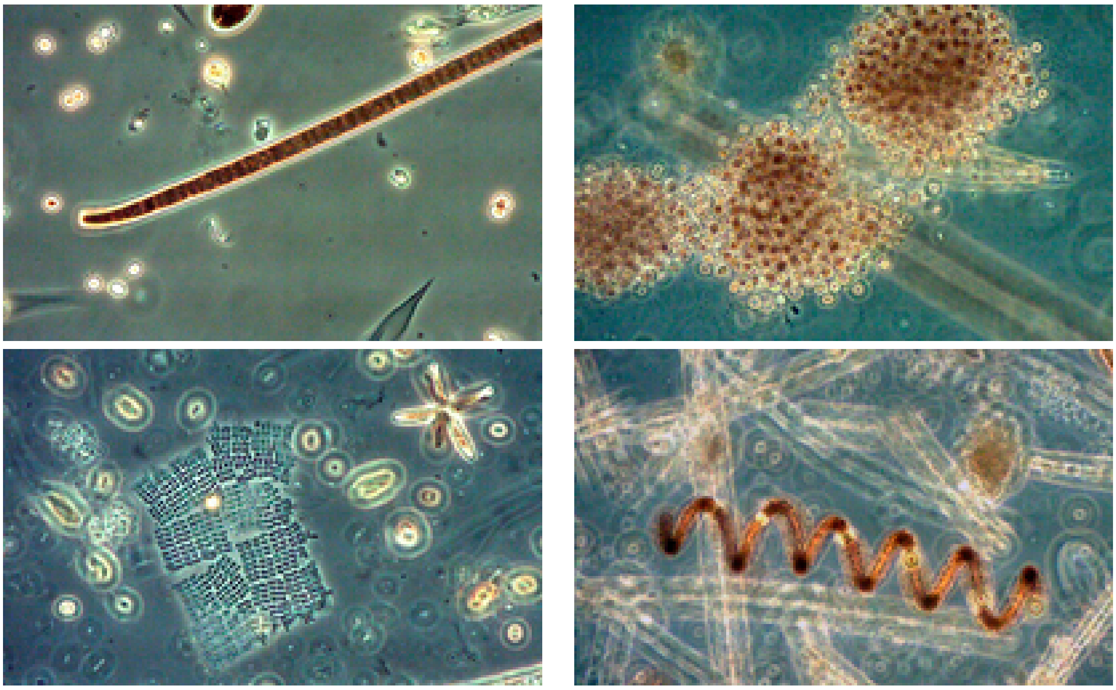


Microcystis under the microscope. The photo depicts a real width of around half a millimetre (Eawag).

A reliable method

The researchers ultimately selected four biomolecules that could reflect the fluctuations of various cyanobacteria in Lake Greifensee. These included a member of the toxic microcystins, which can also occur in “Burgundy blood algae” blooms of the cyanobacterium Planktothrix rubescens in other Swiss lakes. The other three indicator molecules point to various cyanobacteria in the Microcystis genus. Although not all indicator molecules are toxic substances, their occurrence points to the presence of toxic cyanobacteria – even before the actual toxins, such as microcystins, can be measured.

Janssen is confident that these four substances represent a good list of indicators for Lake Greifensee. “You don’t need to measure all possible biomolecules – there’s an easier way to do it. In future, it may be useful for the authorities to only track selected substances in each lake, although you need to know which indicators are relevant to the lake in question,” says the researcher.



Various cyanobacteria: Planktothrix, Microcystis, Merismopedia, Anabeana (from left; photos: Eawag)

The researchers also recommend not relying solely on the measurement of biomolecules but rather – as is sometimes already the case – combining these measurements not only with a measurement of bacterial cell counts in order to determine the number of bacteria per litre of water but also with a method for identifying the predominant species, such as a genetic marker. Together with the indicator substances, this approach provides robust reference points for whether and when a toxic algal bloom is imminent. Moreover, the team also wants to gain a better understanding of how the development of toxic blooms is influenced by the community of other planktonic organisms in the lake, as well as by competition between cyanobacteria themselves.

Now also focusing on near-shore samples

Janssen emphasises that none of the samples analysed using mass spectrometry have a toxin concentration in excess of WHO limits. The situation may be different with samples from areas near the shore. “Benthic” cyanobacteria – which grow on the bed of the lake and find their way to the surface – produce different toxins from those in free water. However, these benthic cyanobacteria can pose an acute hazard to humans and animals on a temporary basis and in a localised area, such that bathing is not recommended. Accordingly, in 2025, the team of researchers from Eawag is now also addressing this topic and testing Lake Greifensee for benthic cyanobacteria for the first time.

What are blue-green algae?

They are not actually algae, but bacteria. Their name stems from the fact that the pigments of cyanobacteria in dense blooms make the water look green, blue-green and brown-green and have historically been mistakenly associated with algae. These bacteria are some of the oldest organisms on Earth and derive their energy from photosynthesis. They produce countless bioactive substances, of which only a fraction has been identified. A few of these substances have been shown to be toxic – acting, for example, as a neurotoxin or liver toxin. If mammals come into contact with them, the consequences can be very serious. This is a particular problem in stagnant water – from small pools which serve as drinking water for livestock, to lakes in which dogs or people bathe. As yet, researchers do not fully understand why the bacteria produce the toxins. Since these toxins are often not released into the environment but rather remain inside the cells, the suspicion is that they not only serve as protective agents but also play a special role in the bacteria's metabolism. See FAQ cyanobacteria/blue-green algae.

Cover picture: Researcher Elisabeth Janssen during sampling at Lake Greifensee (Photo: ETH Board, Daniel Kellenberger).

Original publication

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Related Links

CyanoMetDB: Freely accessible database of metabolites produced by cyanobacteria

Project page

Why do toxic cyanobacteria bloom? A gene to ecosystem approach

FAQs, further information and links relating to cyanobacteria

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