High Frequency Monitoring of Phytoplankton Distribution with special reference to Cyanobacteria in Drinking Water Reservoirs

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1. Abstract

Lakes and dams play an important role in the supply of raw water for drinking water processing as well as for recreation. Both utilisations need a high quality of water to guarantee the health of all involved parties. Worldwide, the water in reservoirs used for drinking water production is increasingly threatened by the growth of algae and potentially harmful cyanobacteria. *Cyanobacteria* are known for their ability to produce toxins that pose a risk to humans. Therefore, effective risk assessment and management is required in drinking water production to determine the occurrence and levels of cyanobacteria.

The measurement and data evaluation of an *in-vivo* flow-through device enabled the assessment of the algae composition in the raw water inlet and the first treatment steps. The device monitored 24/7 in real time with adjustable alarm thresholds.

In a study, we present the development of microalgae and cyanobacteria in a water treatment plant in Clear Lake, California, over three years (2020-2023). Various techniques were used to monitor the water for phytoplankton composition, *microcystin* and *unbound-phycocyanin.*

In depth profiles, we show that the algae concentration is strongly depth-dependent and in some cases reaches a cyanobacteria maximum precisely at the inlet of the drinking-water treatment plants.

2. Toxins

2.1 Microcystins

Cyanobacteria contain a wide range of different active substances, some of which are very toxic. Depending on their effect, these “cyanotoxins” can be divided into hepatotoxins (liver toxins), cytotoxins (cell toxins), neurotoxins (nerve toxins), as well as inflammatory and skin-irritating substances. There is also evidence of genotoxicity for some (of these) substances from cyanobacteria and that they trigger or promote tumor growth. In addition, non-specific symptoms such as irritation or allergic reactions of the skin, digestive tract, respiratory tract, eyes, and ears are often reported after contact with cyanobacteria, although these can rarely be clearly attributed to individual substances or toxins. The WHO has limit values of 1 µg/L for drinking water and 25 µg/L for bathing water.

The most widespread toxin is micorocystin, which is present in 50 % of the cyanobacteria Microcystis. The microcystin LR is a basic form (see Fig. 1) and there are many different variants with linked amino acids.

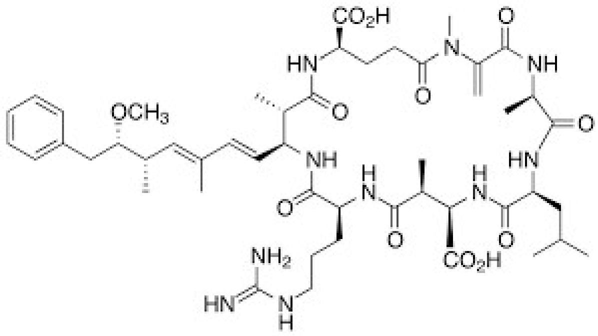


Fig. 1: (wikipedia) Microcystins are cyclic heptapeptides with different amino acids

2.2 Anatoxin

The much more dangerous anatoxin is a neurotoxic alkaloid produced by a variety of cyanobacteria (see Fig. 2). ATX-a and HATX-a as well as their dihydro variants act as analogs of acetylcholine, i.e. they transmit stimuli between nerve and muscle. However, as these cyanotoxins are not broken down by acetylcholinesterase, acute poisoning leads to overstimulation and paralysis of muscles and ultimately to respiratory arrest.

Anatoxin producing species are Oscillatoria, Cylindrospermum, Cuspodothrix

No limit values are set by the WHO for anatoxin. Various studies have set the limit values for anatoxin at 30 µg/L for drinking water and 60 µg/L for bathing water.

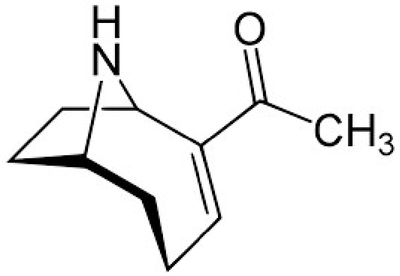
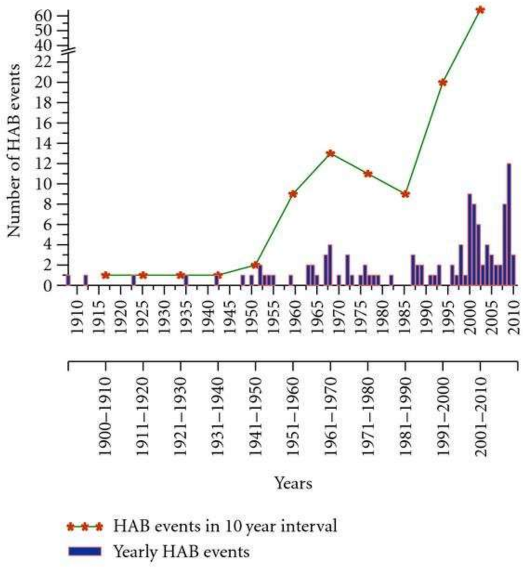


*Fig. 2: Amatoxin-A also known as **Very Fast Death Factor** (VFDF)*

3. Harmful Algae blooms (HAB)

HABs are widespread worldwide and pose a threat to a wide variety of living organisms. Documented HABs have increased significantly over the last hundred years (Fig.3.)



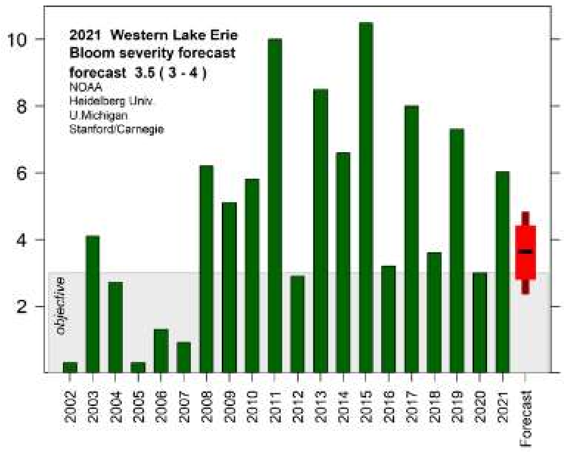


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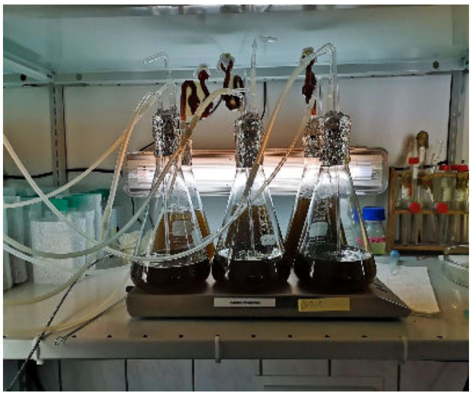
Fig. 3: Worldwide increase of HAbs and increase at Lake Erie

4 How to measure Cyanobacteria

Besides Microscopy and HPLC, Fluorescence measurement is an important tool to estimate the amount of Cyanobacteria. A multiwavelength fluorescence device can separate 5 algae classes. However, for a correct estimation of the algae concentrations, calibration should be done with living algae, and interference effects (including fluorescence of yellow substances (CDOM), and the fluorescence reduction due to Turbidity) must also be measured.



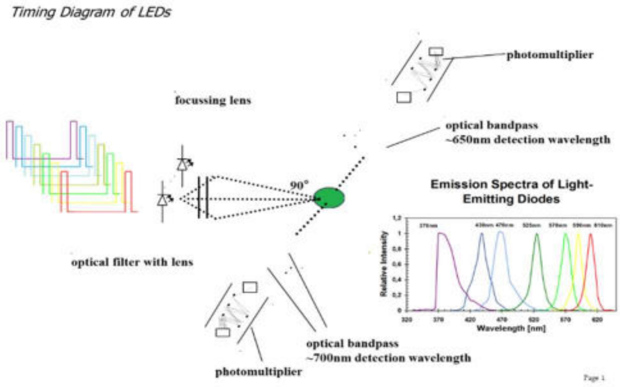


Fig. 4: Pure algae solutions are necessary for good calibration results. Timing diagram of a Fluorometer

5 Depth distribution of Algae

The cyanobacteria have a strong depth dependency. Very high concentrations of cyanobacteria are often found in the thermocline region between 9 and 15 metres water depth. Many waterworks pump water from this depth for their drinking water production.

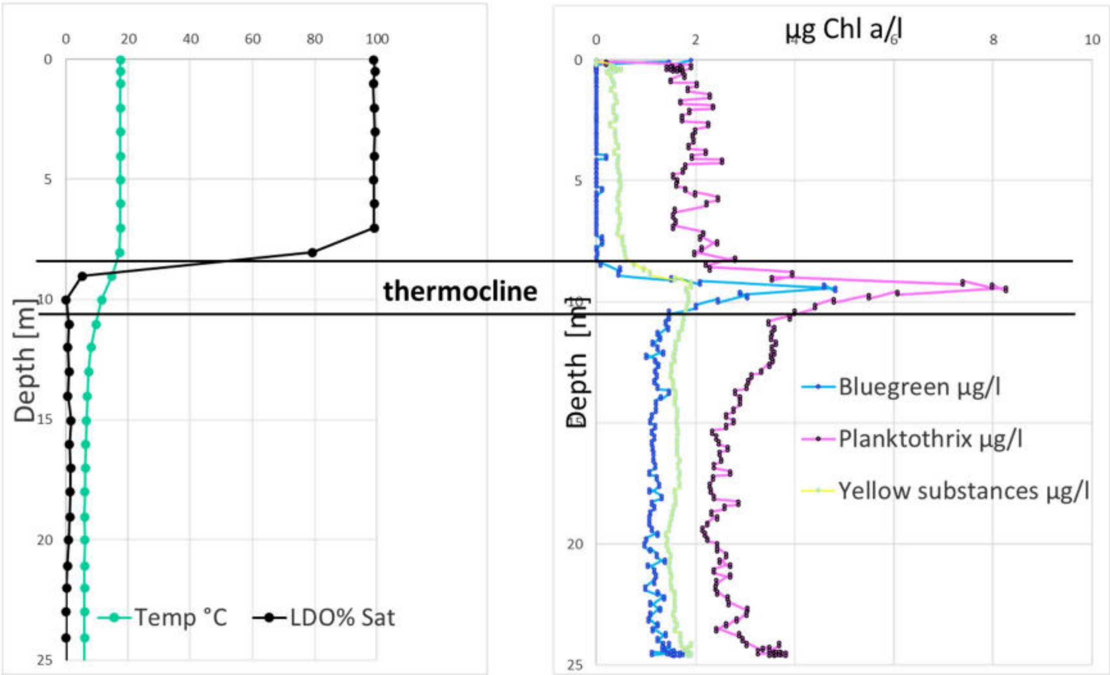


Fig. 5: Depth dependence of cyanobacteria

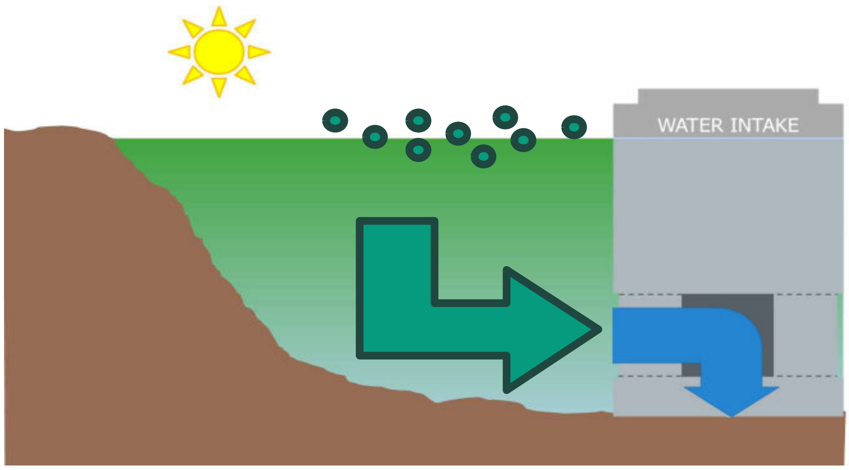


Fig. 6: High concentration of Cyanobacteria could enter the drinking water plant

7 Extended Study at a Water Treatment Plant

The operator of the Buckingham Park treatment plant measured the Algae distribution once a week over a period of three years. Over this timeframe, the concentration of Cyanobacteria increased 4 times from 10µg Chla/L to 40 µg Chla/L. These dramatic increases needed to be monitored to ensure that no toxins reach the drinking water.

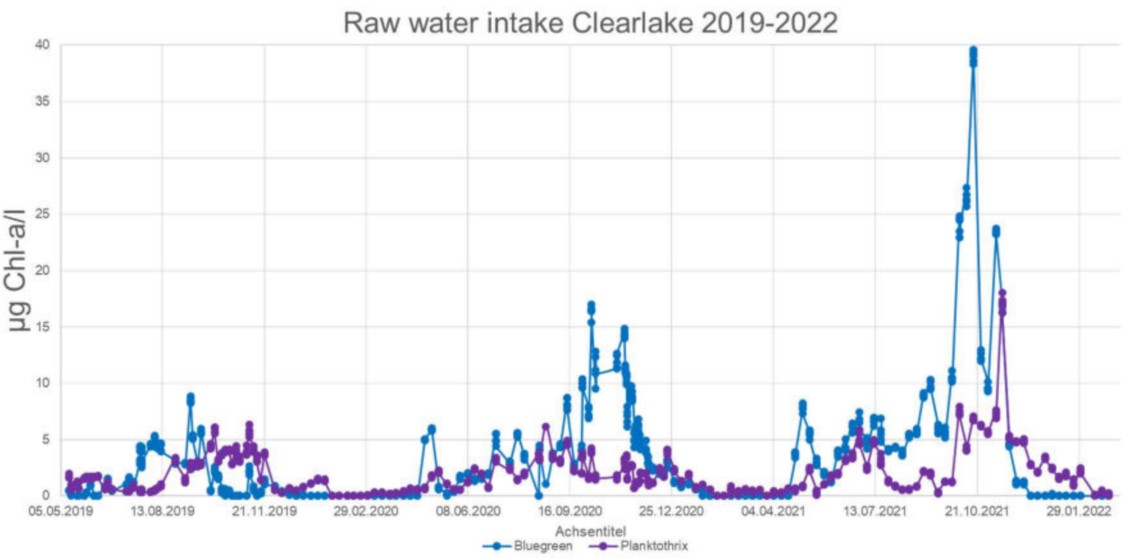


Fig. 7: Cyanobacteria and their relevance for waterworks

6 Applications at Water Treatment Plants

At large reservoirs and natural lakes that are used for drinking water production, online measuring devices are often used to determine the composition of algae. This makes it possible to optimize the treatment stages in the waterworks. If there are large amounts of cyanobacteria, additional treatment stages, e.g. carbon filters, can be implemented. Case studies from Solingen, Toledo, Toronto, and Kentucky show the simple integration of algae flow systems to enable 24/7 data recording and capture the dynamics of the algae.

Fig. 8: Example of an AlgaeOnlineAnalyser at the water treatment plant in Toronto