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Anticipating pathways and timing for cyanobacteria breakthrough at a 2-lake bank filtration site via environmental tracers

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Abstract. Cyclic presence of different types of phytoplankton, including cyanobacteria, in the lakes at various depths and eventually at some wells was observed at a 2-lake bank filtration site. Due to their potentially high toxicity, understanding the origin and pathways of cyanobacteria is crucial to maintain the security of the drinking water supply. Measurements of temperature were carried out at Lake B from February 2017 to May 2018 in order to better understand the lake's dynamics. We determined that complete mixing of the water column occurred from mid-October to mid-November. By anticipating the extent and the timing for the autumnal turnover, one can adjust management strategies. This work is the first step towards a better understanding of the controlling factors over cyanobacteria breakthrough.

Key words. Lake bank filtration; lake stratification; mixing ratios; pumping schemes; cyanobacteria.

EXTENDED ABSTRACT

Background

Bank filtration systems were proven to be effective for the removal of cyanobacteria and associated toxins when sufficiently long travel times prevail, allowing for biodegradation to occur [1]. There is no standard minimum travel ensuring adequate removal of cyanobacteria, because the efficiency depends on numerous site-specific factors such as the colmation layer (i.e. sediments at the surface water/aquifer interface) [2]. Pazouki, Prevost [3] demonstrated the passage of various phytoplankton, including cyanobacteria cells, at a 2-Lake BF system in Quebec and highlighted the importance of having an intensive monitoring program to detect future breakthroughs. They reported that cyanobacteria species observed at the pumping wells were similar to the species found in Lake B (compared to species observed at Lake A and in the lakes' sediments). Higher phycocyanin relative fluorescence units (PC RFU) were measured at 10m depth in Lake B (compared to 0.5m, 1m and 5m depth) and at all depths in October 2013. Increase in PC RFU in the lakes also coincides with higher counts in the pumped water. In sum, the results of the investigation conducted by Pazouki, Prevost [3] point out that the similitude between the observed cyanobacteria species at Lake B and at the pumping wells is due to insufficiently long travel times. In comparison, longer travel times prevail between Lake A and the pumping wells.

In this context, the BF more effectively removes cyanobacteria. Hence, it seems that this 2-Lake BF system could be more vulnerable to cyanobacteria contamination originating from Lake B. Understanding the dynamics of Lake B appears important to anticipate pathways and timing for cyanobacteria breakthrough. The aim of the present work was to assess the (1) extent and (2) timing of the autumnal turnover of the water column in Lake B.

Materials and methods

Physico-chemical parameters, including temperature, electrical conductivity (EC), pH and redox potential, of Lake B were measured using a multiparameter probe assembled with a 30-meter long cable (YSI Pro Plus multiparameter meter with Pro Series ph/ORP/ISE and Conductivity Field Cable). Measurements were performed with a depth interval of 1m in the middle of the lake from March 2017 to May 2018. During periods of limited access to the lake (i.e. ice-cover formation or removal periods), the same measurements were performed only at the surface of the lake from nearshore.

Continuous measurements of temperature were conducted in Lake B from September 11, 2017 to May 15, 2017. Three temperature sensors (iButton®; DS1922L; accuracy ± 0.5 °C; resolution 0.0625 °C) were installed at 7m, 9m and 13.5m from the surface of the lake (measured on September 11).

Results and discussion

Timing of the automnal turnover at Lake B

Evolution of temperature at various depths in Lake B is shown on Figure 1. The monitoring started on March 2, 2017. During wintertime, water temperatures are typically minimal and show an inverse thermal stratification, ranging from 3.6 °C (at 2m depth) to 5.1 °C (at 14m depth). A few weeks later, water temperature at the surface of Lake B started to rise and reached 9.2 °C on April 19, 2017. Warming of the entire water column continued throughout summertime, resulting in the development of a strong thermal stratification. Maximal temperature (23.3 °C) was observed at 2m depth on August 7, 2017. On October 26, 2017, the upper part of the lake (0-4m depth) showed a homogenous temperature (~ 14°C), indicating that the mixing of the water column was possibly already initiated. In the meantime, water temperatures in the bottom part of the lake (5-13m) ranged from 13.5°C to 6.6°C. From October 28 to November 7, 2017, water temperature at 7m rose from 9°C to 10.5°C, prior to going through a rapid cooling. The same trend, but with less intensity, was also observed at greater depths (9m and 13.5m) from mid-November to early December. Mixing of the water column occurred over a 1-month period from mid-October to mid-November. Then, water temperatures at 7m, 9m and 13.5m stabilized at ~4°C for few days on early December. During winter 2018, we observed a slow and gradual warming of the entire water column; except for the most surficial part (0.1-1m). In fact, the first centimeters showed cooler temperature due to water-air heat transfer (air temperatures being below 0°C).

Implications for water management

Studies showed that thermal stratification typically limits exchanges between the different layers of lakes. Nutrients and dissolved oxygen can thus go through a gradual depletion over summertime due to biological activity. However, autumnal turnover allows for the mixing of the water column. This vertical mobilization of water can drive nutrients and oxygen renewal at depths where low concentrations were potentially inhibiting development of microorganism prior to the autumnal mixing [4]. We demonstrated that the autumnal turnover occurred from mid-October to mid-November. We thus suggest that water managers adapt the pumping strategy according to the lake's dynamics.

The results of the present investigation highlighted that continuous measurements of temperature at various depths allow us to easily characterize the timing of the autumnal turnover. Other measurements, such as stable isotopes of water and electrical conductivity, would be helpful to track geochemical shift associated with the lake turnover in the bank filtrate. Such information could help with developing a precursor to anticipate for potential cyanobacteria breakthrough.

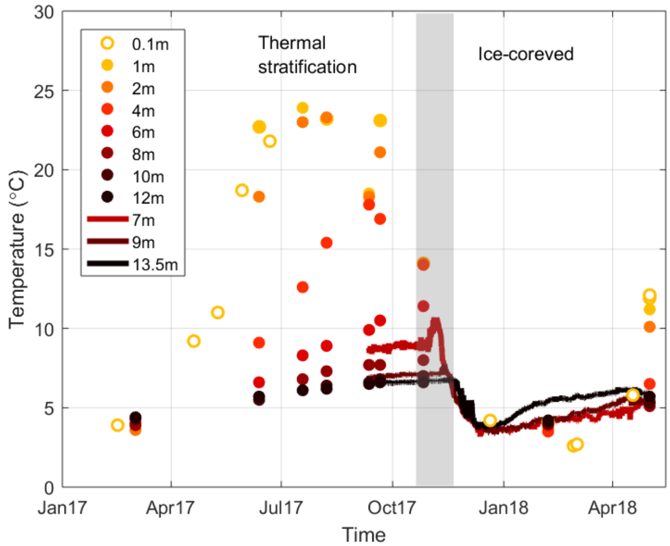

Figure 1. Temporal evolution of water temperature in Lake B at various depths. Discrete measurements (circles) were performed with a YSI multiparameter probe, whereas submerged iButtons allowed for continuous measurements (solid lines). The grey shaded area illustrates the period of the autumnal turnover.

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