MONITORING A TOXIC CYANOBACTERIA BLOOM IN LAKE BOURGET (FRANCE) AND ITS CONSEQUENCES FOR WATER QUALITY

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ABSTRACT

This work describes the appearance of a toxic cyanobacterial bloom in Lake Bourget (France) in the winter 98/99 and its effect on the quality of the water that supplies two population centers. The horizontal distributions of the *Planktothrix rubescens* filaments were very similar in the three sampling stations and the vertical distributions were homogeneous from 0 to 140 m depth after complete mixing of the lake (January 1999). Before that, *P. rubescens* filaments were mainly located in the epilimnion and metalimnion. A microcystin-RR was identified by HPLC analysis. The RR-microcystin concentration in the lake was higher than 4 µg l⁻¹ at the maximum of the bloom, while the concentrations in drinking water were always below 1 µg l⁻¹. This event shows that a large decrease in phosphorus concentration in the lake over the past 10 years, and pumping deep water (30 m) for water supply are not sufficient to avoid problems with cyanobacteria.

INTRODUCTION

*Planktothrix* (*Oscillatoria*) *rubescens* is very common in sub-alpine and other lakes in central and northern Europe [1]. This species can form blooms and produce toxins such as microcystins and anatoxin-a [2]. Thus, a *P. rubescens* bloom in a lake whose water is used for human consumption or for recreation must be monitored.

There have been problems with this organism in Lake Bourget over the past two years. A *P. rubescens* bloom in November 1998 sharply increased the turbidity of the water in treatment units providing drinking water. These central supplies obtain their lake water from a depth of 30 m. We have surveyed this new phenomenon by studying the spatial and temporal distributions of *P. rubescens* in the lake and estimated the microcystin concentrations before and after water treatment.

MATERIAL AND METHODS

Lake Bourget is a large (45 km²), deep (140 m at the point B) lake in the French Alps (Fig. 1). Water samples were taken at 3 points (B : northern lake, M : middle of the lake and T : southern lake) twice a month, to evaluate the horizontal distribution of *P. rubescens*. Samples (2 liters) were taken at depths of 3, 10, 15, 30, 45 and 65 m. 300 ml of each of them were preserved in Lugol’s iodine solution for microscopic enumeration. 200 µm units of *P. rubescens* filaments were counted using the Utermöhl inverted microscope technique after sedimentation of 25 or 50 ml water. Estimation of the number of cells was obtained knowing that the mean length of a *P. rubescens* cell (estimated on 100 measurements) was 5 µm.

Microcystins were extracted from 1 liter of water by the protocol of Feuillade et al. [3]. The samples were taken in the water treatment units, before (water intake in treatment unit) and at the end of the treatment steps (in water reaching the consumers). Intracellular microcystins were identified and quantified by high-performance liquid chromatography (HPLC). The eluting compounds were detected by photodiode-array UV spectroscopy (Waters). Identification of toxins was realized on their retention time and on their UV spectra (absorbance maximum at 238 nm). The amount of microcystin was estimated by measuring the area of the UV absorption peaks at 238 nm and quantitation (Millennium Software from Waters) was made using a mcyst-RR and a mcyst-LR calibration curve. These two microcystins were purchased from SIGMA.

Fig. 1. Location of Lake Bourget in France. B, M (Mémard) and T (Tresserve) are the three sampling stations for this study

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RESULTS AND DISCUSSION

The vertical distributions of *P. rubescens* in the three sample areas (M, T & B) were very similar (Fig. 2). In December 98, the filaments were located above the thermocline with a maximum density (> 20000 cells ml⁻¹) at 30 m depth. There was a small difference in the depth of the thermocline at the beginning of the month, deeper at points M and T (50 m) than at point B (35 m). This was due to the strong dominant north wind at this time of year (data not shown), which deepens the thermocline in the southern lake.

From January to the end of the bloom in March 99, the cell concentration, similar throughout the water column, slowly decreased. At point B, the density was the same from top to bottom (140 m) from January to March as a result of complete mixing of the lake.

The spatial distribution of *P. rubescens* in the water column is very interesting as there are no published reports of a homogeneous distribution of this cyanobacterium from the surface to the bottom in a deep lake. Micheletti *et al.* [4] showed that *P. rubescens* occupies the metalimnion (10-15 m) in lake Zürich in summer and gradually spreads to the epilimnion in autumn. Filaments were found in the epilimnion throughout the year in lake Nantua [5].

The cell concentration of *P. rubescens* in the untreated water of the two central water supplies (Fig. 3) was significantly (p < 0.05) correlated with the one estimated in the lake at 30 m (Pearson correlation coefficient r = 0.94 for Mémard and r = 0.98 for Tresserve supplies respectively).

There was also a significant correlation (p < 0.05) between the numbers of cells before and after water treatment in the Mémard central supply (r = 0.9), but not in Tresserve (r = 0.6) (Fig. 3). This phenomenon was probably due to differences in the performances of water treatment protocols used in the two treatment units. Differences in the cell concentrations were especially significant from January to March, after the treatment protocol in the Tresserve unit was changed (Fig. 3). These changes concerned the washing of the sand filters (every day instead three times a week) and the quantity of ozone used (4 g/m³ O₃ instead of 3 g/m³). This change was followed by a strong decrease of the cell concentration in the water at the 01/13/1999.

Most of the microcystin (> 90 %) found in the cellular extracts was mcyst-RR. There was a good linear correlation (Mémard, r = 0.8; Tresserve, r = 0.9; p < 0.05) between the number of *P. rubescens* cells and the microcystin-RR concentration in water before treatment (Fig. 3). There were several intracellular microcystin-RR concentrations above 0.5 µg l⁻¹ in treated water during three weeks in December 1998 and January 1999 but no extracellular toxin was detected by HPLC, in treated water throughout the study period (data not shown).
A drop in the level of the ground water has resulted in surface water being increasingly used as a source of drinking water. Falconer et al. [6] have recommended that the water body used for domestic consumption should be selected on the basis of its history (cyanobacterial blooms), nutrient concentration (total phosphorus < 10 µg P l⁻¹) and hydrodynamic regime. In Lake Bourget, the total phosphorus is over 10 µg P l⁻¹ after complete mixing of the water in winter. But phosphorus concentration was six times higher in the Eighties and there were never any cyanobacterial blooms. So, the reduction of phosphorus concentration is not always sufficient to prevent cyanobacterial bloom formation. In Lake Nantua, the decline in phosphorus inputs has resulted in *P. rubescens* population sinking to the metalimnion rather than causing a major reduction in the cyanobacteria biomass [5]. In the same order, Mez et al. [7] have observed cyanobacterial blooms in oligotrophic lakes from Switzerland.

Hrudey et al. [8] pointed out that the vertical movement of cyanobacterial populations must be known in order to select the best depth for withdrawing drinking water to avoid contamination. Taking water from depth generally avoids problems of cyanobacteria. The bloom in Lake Bourget shows that this generality does not always overcome problems with cyanobacteria in deep lakes because complete mixing of the water in winter distributes the filaments throughout the water column.

The concentrations of intracellular microcystin-RR in drinking water were always below the maximum dose (1 µg l⁻¹) of microcystin-LR recommended by the WHO [9], which is considered to be more toxic than microcystin-RR [10]. However, the human health risk resulting from chronic exposure to this toxin is very difficult to estimate. We are therefore preparing an Alert Levels Framework (monitoring and management action sequence) for Lake Bourget and the pumping of ground water has been re-instituted for use during the blooms.

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REFERENCES