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Spatial and temporal variations of two cyanobacteria in the mesotrophic Miyun reservoir, China

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ABSTRACT

Spatial variations in phytoplankton community within a large mesotrophic reservoir (Miyun reservoir, North China) were investigated in relation to variations in physico-chemical properties, nutrient concentrations, temperature and light conditions over a 5 month period in 2009. The dynamics of phytoplankton community was represented by the dominance of cyanobacteria through summer and fall, following with a short term dominance of chlorophyta in late fall, and a relatively high abundance of diatom in October; on the other hand, maximum phytoplankton biomass was recorded in the north shallow region of Miyun reservoir with a higher nutrients level. Particular attention was paid to the impacts of environmental conditions on the growth of two cyanobacteria genera, the toxin-producing *Microcystis* and the taste & odor-producing *Oscillatoria*. *Microcystis* biomass was in general greatly affected by water temperature and mixing depth/local water depth ratio in this reservoir, while the *Oscillatoria* biomass in the surface and middle layers was greatly affected by total dissolved phosphorus, and that in the bottom layer was related with the Secchi depth/local water depth ratio. Abundant *Oscillatoria* biomass was observed only in late September when *Microcystis* biomass decreased and allowed sufficient light go through.

Introduction

Construction of reservoirs has become the main way in securing drinking water source in the world (Kwak and Russell, 1994). However, deterioration of water quality characterized with the abnormal growth of algae frequently occurs once the river-type source water is replaced by the reservoir-type water (Codd, 2000; Šimek et al., 2011; Zhao et al., 2011). Cyanobacterial blooms associated with the taste & odor (T&O) problems and algal toxins (cyanotoxins) have become one of the major issues for reservoir management and attracted intensive research concerns (Graham et al., 2010; Li et al., 2012a; Zamyadi et al., 2012). Until today, most of the previous studies have mainly focused on the occurrence of harmful algae blooms (HAB) in the eutrophic reservoirs (Naselli-Flores, 2011; Paerl et al., 2011; O'Neil et al., 2012). Regional algal blooms occurring in oligotrophic and mesotrophic drinking water reservoirs, which could become a threat to drinking water supply, has often been ignored.

Miyun Reservoir, a large reservoir with an average depth of approximately 20 m, is the major surface-source of drinking water for Beijing City, and has been kept in the mesotrophic state through a set of strict environmental protection measures. However, two well-known cyanobacterial metabolites, 2-methylisoborneol (MIB) and microcystin-LR (MC-LR), have been detected in the source water taken from this reservoir in recent years, with the concentrations up to 150 ng/L (Yu et al., 2007) and 41 ng/L (Zheng et al., 2007), respectively. Two-methylisoborneol, a notorious T&O compound, is mainly produced by filamentous and coccoid cyanobacteria including *Oscillatoria* sp. (Izaguirre et al., 1999; Izaguirre

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et al., 2007), *Phormidium* sp. (Izaguirre et al., 2007), *Pseuadanabaena* sp. (Izaguirre et al., 1999) and *Synechococcus* sp. (Izaguirre et al., 2007) etc. Although no evidence has shown that MIB is toxic to human health, occurrence of odor can make consumers to suspect the safety of drinking water. So the complaints from customers could significantly increase when a T&O episode occurs (Smith, 2002), which could not be neglected by water supply industries. The microcystin-producing genera that are of major importance in phytoplankton have been identified as *Microcystis* sp. (Tillett et al., 2000), *Anabaena* sp. (Rapala et al., 1997) and *Planktothrix* sp. (Christiansen et al., 2003). Among the suspected species, *Oscillatoria* sp. and *Microcystis* sp. account for the majority of T&O and microcystin events in Miyun Reservoir respectively, according to previous phytoplankton surveys (data not shown). Therefore, the occurrence and distributions of both genera in Miyun Reservoir could significantly impact the drinking water quality. As a benthic cyanobacteria, *Oscillatoria* sp. is commonly present on the shallow shore with a good transparency, while the bloom forming *Microcystis* sp. tends to occur at the surface of eutrophic water bodies (Wilhelm et al., 2011; Acuňa et al., 2012). Thus, it is interesting why the two cyanobacteria with contradictory habitats grow in the deep Miyun Reservoir with a low nutrient level, and it is important to reveal the temporal and spatial variations of nutrients and phytoplankton community for establishing a strategy on controlling their growth.

In the present work, continuous survey covering different regions of Miyun Reservoir was performed over a period from June to October in 2009, shows that the temporal and spatial variations of phytoplankton community and physico-chemical properties of the reservoir including water temperature, dissolved oxygen (DO), pH, water transparency and nutrient concentrations. This work attempted to identify the impacts of environmental conditions in Miyun Reservoir on the potential MIB and MC-LR producers; the result of the study could assist decision makers in managing water quality related issues in drinking water reservoirs.

1 Materials and methods

1.1 Study site

Miyun Reservoir, located 100 km northeast of Beijing (40°30′N, 116°55′E), is the main drinking water storage for Beijing. The water level of the reservoir dropped from the highest record of 153.98 m (above sea level) in 1994 to 137 m (above sea level) in 2012, which is mainly due to continuous drought from 1999 to 2004 and overuse (Ma et al., 2010). The reservoir is characterized with a large area (total volume: 4.375 km^3; surface area: 188 km^2; maximum depth: 60 m) and complex bathymetry (a mountain valley reservoir). A bathymetry map was obtained from the interpolated depth data collected from an Acoustic Doppler Current Profiler instrument (ADCP, LAUREL, USA), as shown in **Fig. S1**. The reservoir can be divided into four parts according to the bathymetry characteristics: the west deep region and south deep region are relatively deep (maximum water depth, z_{max}: 36 m; mean water depth, z_{ave} > 20 m) compared to the north shallow region (z_{max}: 10 m; z_{ave}: 6 m) and northeast shallow region (z_{max}: 14 m; z_{ave} < 5 m). The northeast shallow region is characterized with a relatively high turbidity due to the inflow. As shown in **Fig. 1**, two main inflows, Bai River and Chao River, enter the reservoir via two large inlets and maintain the reservoir's water capacity; the main outflow is a channel located in south deep region flowing to drinking water plants, while the Bai Release Channel is normally closed.

1.2 Sampling

Water survey was performed once a month during June 2 to October 26 in 2009, except in September when 3 campaigns were conducted because of the occurrence of high *Oscillatoria* density. According to the bathymetry, hydrological and geochemical characteristics of the reservoir, a total of 8 sampling sites (MY01–MY08) (**Fig. 1**). MY01, MY07 and MY08 are located in the deep region, close to Bai Dam and Chao Dam, respectively; MY02 and MY03 are close to the largest upstream – Bai River; MY05 is in the north shallow region; MY04 is in the ship channel with frequent disturbance from boats; MY06 is in the edge of north shallow region with a depth around 10 m. Eleven extra sampling sites MY09–MY19 were used

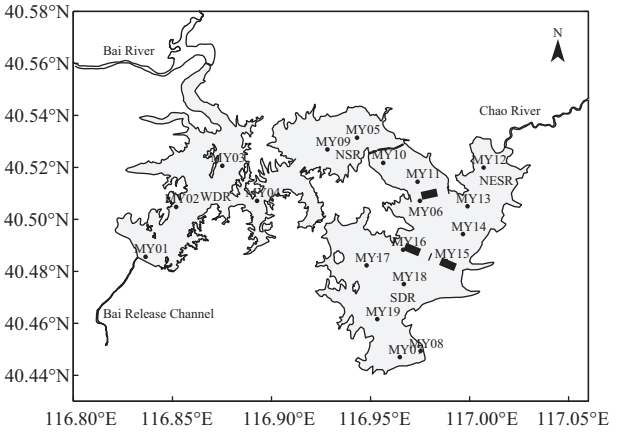

Fig. 1 Map of Miyun Reservoir and the sampling sites. MY01–MY08 are routine field sampling sites, while MY09–MY19 were used in September to get more information for *Oscillatoria* sp., where the detection of physico-chemical parameters and nutrients, as well as algal enumeration were performed. Bai River and Chao River are the two main inflow rivers, and Bai Release Channel is a manual controlled outflow for agriculture etc.; MY07 is water intake position to drinking water supply. WDR: west deep region; NSR: north shallow region; NESR: northeast shallow region; SDR: south deep region.