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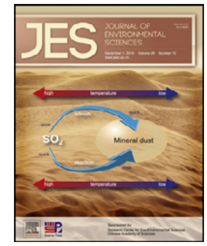

Effects of seasonal climatic variability on several toxic contaminants in urban lakes: Implications for the impacts of climate change

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ABSTRACT

Climate change is supposed to have influences on water quality and ecosystem. However, only few studies have assessed the effect of climate change on environmental toxic contaminants in urban lakes. In this research, response of several toxic contaminants in twelve urban lakes in Beijing, China, to the seasonal variations in climatic factors was studied. Fluorides, volatile phenols, arsenic, selenium, and other water quality parameters were analyzed monthly from 2009 to 2012. Multivariate statistical methods including principle component analysis, cluster analysis, and multiple regression analysis were performed to study the relationship between contaminants and climatic factors including temperature, precipitation, wind speed, and sunshine duration. Fluoride and arsenic concentrations in most urban lakes exhibited a significant positive correlation with temperature/precipitation, which is mainly caused by rainfall induced diffuse pollution. A negative correlation was observed between volatile phenols and temperature/precipitation, and this could be explained by their enhanced volatilization and biodegradation rates caused by higher temperature. Selenium did not show a significant response to climatic factor variations, which was attributed to low selenium contents in the lakes and soils. Moreover, the response degrees of contaminants to climatic variations differ among lakes with different contamination levels. On average, temperature/precipitation contributed to 8%, 15%, and 12% of the variations in volatile phenols, arsenic, and fluorides, respectively. Beijing is undergoing increased temperature and heavy rainfall frequency during the past five decades. This study suggests that water quality related to fluoride and arsenic concentrations of most urban lakes in Beijing is becoming worse under this climate change trend.

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Introduction

The impacts of climate change on aquatic environment have attracted extensive attention among governments and scientists worldwide over the recent years. Climate change is associated with changes in long-term weather conditions including precipitation, temperature, wind speed, and sunshine duration as well as short-term extreme weather events (Larsen et al., 2011; Mitsch and Hernandez, 2013; Xia et al., 2012). Impacts of climate change on water quantity have been widely studied (Park et al., 2011; Ferrer et al., 2012; Mu et al., 2013). These effects coupled with climate change would further influence the water quality and aquatic ecosystem directly or indirectly.

Compelling evidences have been reported that increasing temperature may alter the biotransformation of contaminants to more bioactive metabolites and induce contaminants such as persistent organic pollutants (POPs) releasing from sediments or ice (Noyes et al., 2009; Whitehead et al., 2009; Petrovic et al., 2011). Ma et al. (2011) analyzed records of the concentrations of POPs at the Zeppelin and Alert Stations in Arctic air since the early 1990s and compared it with the model simulation results of the effect of climate change on their atmospheric abundances; they suggested that a wide range of POPs stored in the ice or water had been remobilized into the Arctic atmosphere over the past two decades due to climate warming. Dissolved ions and heavy metal in Arctic lakes also showed an increasing trend due to enhanced temperature induced snow melt (Macdonald et al., 2005; Zhulidov et al., 2011; Liu et al., 2012). For instance, Thies et al. (2007) observed a substantial increase in solute concentration at two alpine lakes (Rasass See and Schwarzsee ob Solden) in European Alps, in which electrical conductivity increased by 18-fold and 3-fold during the past two decades, respectively. Variations in precipitation linked with climate change would affect water quality through influencing wet deposition and diffused pollution of chemical contaminants. It has been reported that a 20% increase/decrease in precipitation could result in a 53% and 4% decrease/increase in perturbed air concentration of γ-hexachlorocyclohexanes (HCHs) and α-HCH, respectively (Ma and Cao, 2010). Jeppesen et al. (2009) predicted that the phosphorus loading would increase by 3.3–16.5 times to Danish streams due to the increasing precipitation under future climate change scenario A2 during the period 2071–2100. In addition, precipitation induced variations in river flow can influence the concentration of toxic contaminants in the aquatic environment. For example, Petrovic et al. (2011) analyzed 72 pharmaceutical compounds in the Llobregat River at its mouth in Mediterranean, and showed that the concentration of chemical pollutants exhibited a variability of the same order as riverflows. Therefore, variations in climatic factors coupling with each others may have a profounding influence on transformation and migration of environmental contaminants in the aquatic system.

However, most studies about response of water quality to climate change focus on remote arctic and alpine water bodies (Battarbee et al., 2012; Todd et al., 2012). In urban area, the redistribution and transformation of contaminants will also be affected by variations in precipitation, temperature, and wind speed as well as sunshine duration. Therefore, we hypothesize that environmental contaminants in the lakes of urban areas are likely be susceptible to variations in climatic factors, and these effects may be different among lakes with different contamination levels.

In this research, twelve lakes in urban areas of Beijing were selected to study the response of toxic contaminants, including volatile phenols, fluorides, arsenic, and selenium which are rarely studied so far, to the variation of climatic factors. Apart from the toxic contaminants, general physical parameters such as pH, dissolved oxygen (DO), conductivity, secchi depth, and water temperature were monthly measured from 2009 to 2012. The concentration and distribution of contaminants were assessed. The effects of seasonal climatic factors (air temperature, precipitation, wind speed, and sunshine duration) on toxic contaminants were studied, and the potential key climatic drivers for toxic pollutant concentration variations and the effect mechanism were discussed. Accordingly, the effect of climate change on lake water quality was analyzed, and the changing trend of lake water quality in the urban areas of Beijing under the context of climate change was explored and future lake management measures were proposed.

1. Materials and methods

1.1. Site description

Beijing (39°28′N–41°05′N, 115°25′E–117°30′E), the capital of China, is located in the middle latitude, belonging to the eastern warm temperate monsoon zone with semi-humid continental climate and four distinct seasons. Annual precipitation ranges from 470 to 500 mm with uneven temporal and spatial rainfall distribution. In this research, twelve urban lakes with similar water areas and depth were studied. General characteristics and physical parameters as well as locations of the studied urban lakes are shown in Appendix A Tables S1 and S2 and Fig. 1, respectively. The lakes are all located in the recreational parks with similar land use types and covering areas. Water source of Lake Tuancheng comes from Miyun Reservoir, an important drinking water area in Beijing (Fig. 1). Recharge sources of important landscape lakes such as Lakes Qianhai and Houhai mainly come from both Miyun and Guanting Reservoir. As for the general landscape lakes including Lakes Fuhai, Taoranting, Longtan, Qingnian, Lianhua, and Liuyin, recharge sources are mainly from Qinghe, Wujiacun, and No. 6 Water Reclamation Plant in spring season (March to May) and winter season (December), and most water quality parameters of the reclaimed water for landscape water reached Class IV of the national water quality standards, which is the minimum standard for industry and recreation.

1.2. Sample collection and laboratory analysis

The water sampling was carried out monthly except the frozen period (mainly from January to March) from January 2009 to December 2012. The sampling sites were set in the center of the lakes. Secchi depth was measured using a Secchi disk; water temperature, pH, and conductivity of water were measured *in situ* with a multi-parameter meter (Mettler Toledo, SG23, Switzerland). DO concentration was measured with an oxygen meter (Mettler Toledo, SG9-FK2, Switzerland). Water samples for chemical analysis were collected under 0.5 m at the sampling sites and stored in glass bottles.