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Phosphorus fractions and its release in the sediments from the shallow lakes in the middle and lower reaches of Yangtze River area in China

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Abstract

Phosphorus (P) contents and P fractions before and after P release experiments were investigated in the sediments from the shallow lakes in the middle and lower reaches of Yangtze River area in China. The results indicated that the contents of different P fractions in the studied sediments varied greatly. The total P (TP) contents ranged from 221 to 2051 mg kg^{-1}, whereas the loosely sorbed P (NH_4Cl-P) ranged from 1 to 23 mg kg^{-1}, the redox-sensitive P (BD-P) ranged from 48 to 112 mg kg^{-1}, the calcium bound P (HCl-P) ranged from 1 to 129 mg kg^{-1}, and the metal oxide bound P ranged from 180 to 426 mg kg^{-1}. The contents of different P fractions in the sediments were in the order: NaOH-P > BD-P > HCl-P > NH_4Cl-P. Both the contents of different P fractions and the amounts of P released from the sediments have a positive relationship with TP contents in the sediments. This indicated that the heavily polluted sediments (often have high P concentration) have the high potential for P release. It was calculated that over 50% P released was from NaOH-P, over 30% from BD-P, about 10% from HCl-P, and below 5% from NH_4Cl-P; about 50% NH_4Cl-P, 50% BD-P, 20% NaOH-P and 40% HCl-P may be released. It was suggested that NaOH-P and BD-P were the main P fractions (over 80%) that can be released from the sediments into overlying waters, and NH_4Cl-P and BD-P were the main fractions that can be released easily.

Keywords: Trophic status; Lakes; Phosphorus fractions; Phosphorus release; The middle and lower reaches of the Yangtze River area; Sediments

1. Introduction

Lake eutrophication has become a serious environmental problem in China, especially for shallow lakes in the middle and lower reaches of Yangtze River area; it has resulted in serious blue-green algae blooms in the last few years [1]. As a major nutrient for aquatic ecology, phosphorus (P) has been recognized as the most critical nutrient limiting lake productivity [2]. One of the most important factors determining the P concentration of the lake overlying water was the P release from the sediments. Such release may have a significant impact on water quality and may result in continuing eutrophication [3,4]. However, not all of the P fractions can be released from the sediments and render to lake eutrophication [5]. Thus, to assess the risk of eutrophication in aquatic systems, it is necessary to know not only the total P content in the sediments but also the contents of different P fractions. For this purpose, P fractions have been widely investigated [6,7].

The role of the P in lake sediment in promoting lake eutrophication can be more efficiently evaluated on the basis of the contents of different P fractions, instead of total P content [8]. The information of the different chemical P fractions in lake sediments is useful in understanding whether the sediment acts as an adsorber or source of phosphorus [9]. The sediment P can be divided into different fractions such as labile P, reductant P, metal bound P, occluded P and organic P using chemical extractions [10–12]. Moreover, in terms of potential bioavailability, the extracted fractions may be characterized as the loosely sorbed P (NH_4Cl-P), the reductant soluble P (BD-P), the metal oxide bound P (NaOH-P) and the calcium bound P (HCl-P) [7,8], the contents of different P fractions are useful to evaluate the potential P bioavailability of sediments. However, in terms of the P release from the sediment and water interactions, the contributions of different P fractions in the sediments to the released P are

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still unknown. So, the objective of this study was to investigate the changes in contents of P fractions before and after P release experiments and the contributions of different P fractions to the P-loadings of the lake systems were evaluated. The sediments were chosen from nine shallow lakes in the middle and lower reaches of the Yangtze River areas in China.

2. Materials and methods

2.1. Study area

The studied lakes are located in the middle and lower reaches of Yangtze River, the highest lake density area in China (Fig. 1). Most of the lakes are shallow with a large surface area. Total lake surface area in this region is more than 21,000 km^2, accounting for 25% of all water surface area of lakes in China. The number of lake area in this region above 1 km^2 is 651, above 100 km^2 are 18 [13]. Most of the lakes in this area are under mesotrophic or eutrophic conditions due to the township enterprise development, large density of population, the over-use of agrochemical and chemical fertilizers, the discharge of the municipal sewage and the scale cultivation [1], the eutrophication has already become the restriction factor that influences the economic development of this area [14]. Meiliang Lake and Wuli Lake were hypereutrophic [15,16], Gong Lake, East Taihu Lake, Chao Lake, Hongze Lake and Poyang Lake were mesotrophic [17–22], Yue Lake and Xuanwu Lake were urban lakes, have already been hypereutrophic [23]. So, we selected these nine lakes in this study can represent main lake types in the middle and lower reaches of Yangtze River region. The geographic and chemical characteristics of the studied lakes are shown in Table 1 [15–23].

2.2. Sediment sampling and analysis

Eighteen sediment cores were taken from the nine lakes, the lakes ranged from mesotrophication to hypereutrophication (Table 1). The sediment cores were sampled in September 2003 with a core Plexiglas sampler with 30 cm length and 5 cm diameter cylinder tube. Top 10 cm samples were taken to the laboratory in air-sealed plastic bags and kept in cool (4 °C), and they were freeze-dried and ground for experiments. The sediment samples were analyzed for cationic exchange capacity (CEC), total nitrogen (TN) [24] and total P was determined using the SMT protocol [6], water content and loss on ignition measurements were based on weight losses after drying and combustion of the sediments at 105 and 550 °C, respectively. Total organic carbon (TOC) in the sediments was analyzed with an Appollo 9000 TOC Analyzer (Tekmar Dohrman Co., USA) after pre-treatment in warm HCl 50% (v/v) to eliminate inorganic carbon [25]. The contents of major elements in sediments were measured by ICP-AES (P-E, USA, ICP/6500).

2.3. P fraction

The P released from lake sediment mainly originating from inorganic P fraction, so this study the P fractions were focused on the inorganic P fraction. The contents of different P fractions were determined using the sequential extraction scheme of lakes sediment [26]. The 1 M NH_4Cl, 0.11 M $NaHCO_3/Na_2S_2O_4$, 1 M NaOH and 0.5 M HCl were used for sample sequential extraction. The extracts were centrifuged and the supernatants were filtered through 0.45 μm GF/C filter membrane. The soluble reactive phosphorus (SRP) in each sample was determined by the molybdenum blue/ascorbic acid method [27]. This extraction

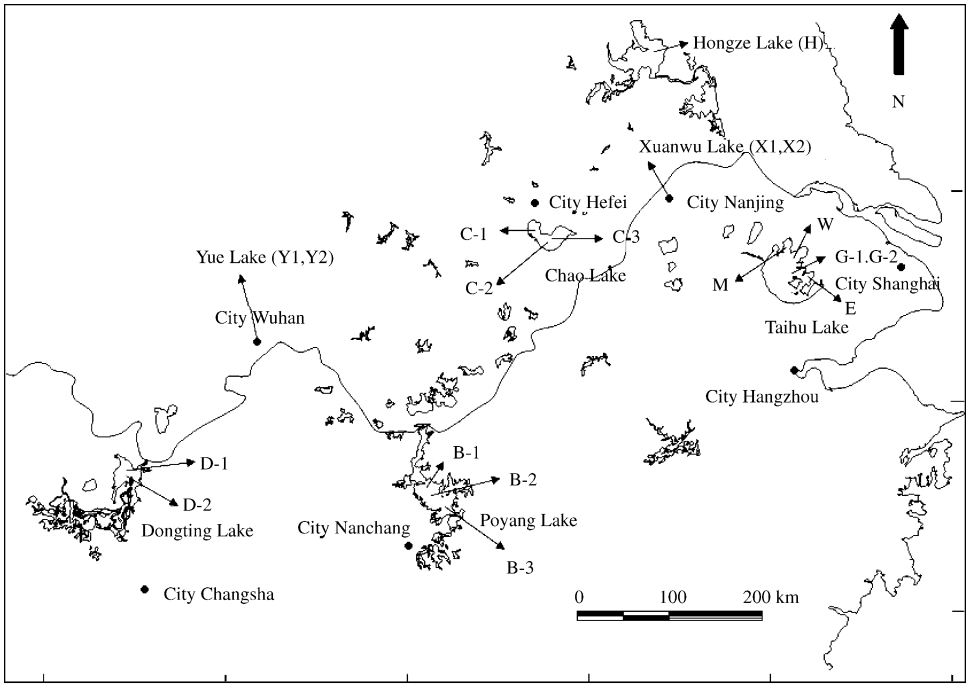

Fig. 1. The geographic location of the sampling sites.