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Vertical Variation of Phosphorus Forms in Core Sediments from Dongping Lake, China

CHEN Shiyue*, CHEN Yingying, LIU Jiazhen, ZHANG Ju, WU Aiqin

[a]*School of Environment and Planning, Liaocheng University, Shandong Liaocheng,China, 252059*

[*]MinChen648@163.com

Abstract

The SMT sequential extraction method was applied to determine content of TP, IP, OP, NaOH-P and HCl-P in the core sediments of Dongping Lake, vertical variation of phosphorus forms and correlations of them and LOI were discussed in this study. Results indicated that TP averaged 548.36 mg/kg, in the range from 498.01 to 596.77 mg/kg and mainly composed of IP (69.26%-79.14%). The three main forms of phosphorus followed the order HCl-P＞OP＞NaOH-P, and HCl-P was the dominant component of TP. All the phosphorus forms had similar vertical distribution pattern under 5 cm (corresponding to 1995), with stable content and narrower fluctuation, and started to present remarkable change above 5 cm, an upward trend in NaOH-P and OP, a downward trend in HCl-P, IP and TP, which indicating that the distribution of phosphorus forms in the sediments was obviously affected by human activities from 1995. Correlation analyses showed that HCl-P was the main factor controlling TP and IP, there were significant correlations between TP and other phosphorus forms except OP, and correlations between phosphorus species (except NaOH-P and OP) were obvious. LOI had obvious correlation with OP and TP, and no relationships with NaOH-P, HCl-P and IP.

Keywords: Phosphorus forms. Sediments. Vertical variation. Dongping Lake.

1. Introduction

Eutrophication has become one of the major water pollution problems throughout China, and phosphorus is regarded as one of the most important limiting factors. Phosphorus in sediments record the impact process of human activities, and its concentration in lakes and rivers results from both external inputs and internal loading from the sediment, once the external source is effectively controlled, its release depends on the form of phosphate in the sediment[1-2]. Therefore, by strengthening studies on mode of occurrence and contents of phosphorus in sediments we can better understand the potential

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activity of phosphorus and determine the source of phosphorus in sediments, meanwhile it has an important meaning in studying eutrophication of lakes and rivers[2-3].

As a large reservoir for flood control and detention at the lower reaches of the Yellow River and an important regulator of the Eastern Route of South-to-North Water Diversion Project in China, water quality assurance of Dongping Lake is of great significance. At the same time, with the rapid economic development and increase in population in recent years, pollutants into Dongping Lake have increased rapidly, and water in the lake worsens day by day (especially from 1998)[4]. Lake nutritional status analysis also indicates that Dongping Lake has been in nutritional level for many years[5]. Water quality status, sedimentary environment and ecological environment of Dongping Lake have been studied at different levels by many researchers[4-6], and Tian et al has studied distribution of phosphorus fractions in the surficial sediments of Dongping Lake. However, investigation on P vertical variation in the sediment is lacking. Therefore, it is necessary to investigate the vertical distribution patterns of the phosphorus forms and their correlations, which will be helpful in studying depositional history of phosphorus in the sediment and providing the basis and reference for eutrophication control of Dongping Lake.

1 Study Area

Dongping Lake (35°30′-36°20′N, 116°00′-116°30′E) is located in Dongping County, west of Shandong Province. It is the second largest freshwater lake in Shandong Province. Current size of Dongping Lake is about 627 km^2, which including the old lake and the new lake. Multi-annual mean depth of Dongping Lake is 2-4 m, with an catchment area of 9064 km^2, recharge coefficient of 61.2, and a total storage volume of 4.0×10^9 m^3[7]. Water of Dongping Lake mainly relies on the surface runoff and lake precipitation supplies, with the Dawen River as the main supply. As guest water collection center of the Dawen River drainage, the detention reservoir of the Yellow River, its leading role is to reduce the Yellow River's flood peak, regulate and store floods of the Yellow River and Dawen River. Besides, Dongping Lake is a pivotal project of the Eastern Route of South-to-North Water Diversion Project of China and water transmission from the west to the east of Shandong Province.

2 Materials and Methods

A 1.65 m long sediment core was taken from the centre of Dongping Lake (35°59′11.6″N, 116°11′35.3″E) in April, 2008 by using an aquatic platform, and was sliced in every 0.5 cm interval at the upper 65 cm, while 1cm interval at the lower 100 cm. It was hard to continue because of the hard lower strata, so another 60-cm-long sediment core (DP) was taken from nearby by using a gravity corer. DP was sliced in every 0.5 cm interval at the upper 20 cm, while 1cm interval at the lower 40 cm. Then numbered consecutively from top to bottom, put them into a plastic box, kept under seal, took back to the laboratory and placed them in cold storage in 4 ℃ refrigerator to prepare for ^{137}Cs and ^{210}Pb analysis. All the samples were carried out at the Key Laboratory of Lake Sedimentation and Environment of Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences.

The SMT sequential extraction method, developed by Ruban[8], was applied to determine content of TP (total phosphorus), IP (inorganic phosphorus), OP (organic phosphorus), NaOH-P (the forms associated with oxides and hydroxides of Al, Fe, and Mn) and HCl-P (the forms associated with Ca) in the core sediments of Dongping Lake. This method is of good accuracy, determination of each phosphorus species is relatively independent, and the measured values can be crosschecked.

Organic matter content is in terms of loss on ignition (LOI): Put the soil samples below 200 meshes into the oven, dried them above 5 hours under 105℃conditions and took about 3 g samples out in porcelain crucible and accurately weighed its quality (accurate to 0.0001g). Secondly, put the samples into the muffle furnace again to dry about five hours and weighed its quality accurately. By calculating we gained 550℃ loss-on-ignition (%), namely the organic matter content.

3 Results and Analyses

3.1 Vertical Variation of Phosphorus Forms in the Core Sediments. As can be observed from Fig. 1, TP content of Dongping Lake is significantly lower, which averages 548.36 mg/kg (498.01~596.77 mg/k), and there is a decreasing trend from the bottom to up. Content of NaOH-P (28.14~52.04 mg/kg) and OP (133.46-185.86 mg/kg) have consistent variation trend, both of them have little change from the bottom to up and a sharp increase from 5 cm, and account for 5.29%~10.45%, 23.64%~37.32% of TP, respectively. HCl-P (286.93~393.82 mg/kg) and IP (344.94~439.75 mg/kg) also have similar variation trend, a slight fluctuation from the bottom to up, a sharp decrease from 5 cm, and account for 57.62%~69.82%, 69.26%~79.14% of TP, respectively.

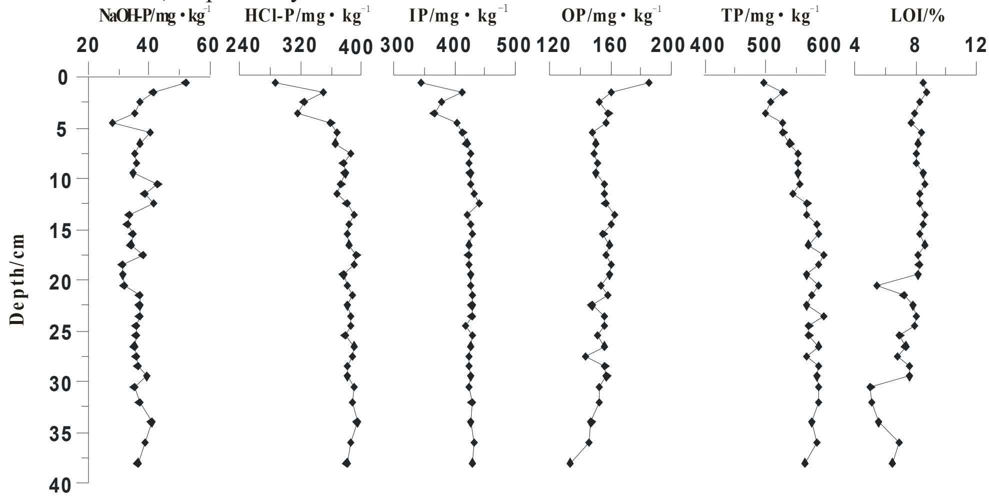

Fig.1 Vertical Variation of Phosphorus Forms and LOI in the Core Sediments

3.2 Correlations of Phosphorus Forms and LOI in the Core Sediments. As is demonstrated in Table 1, TP is high correlated to the HCl-P and IP (0.877 and 0.786, respectively), and has significant correlation with NaOH-P (-0.345), whereas no relationships with OP. But OP is strongly correlated with HCl-P (-0.508) and IP (-0.546). On the other hand, there is significant positive correlation between IP and HCl-P (0.947), whereas negative correlation between IP and NaOH-P (-0.360), significant negative correlation between HCl-P and NaOH-P (-0.462). Besides, LOI is correlated with OP (0.409) and TP (-0.392), and no relationships with NaOH-P, HCl-P and IP.

Table 1 Correlations of Phosphorus Forms and LOI in the Core Sediments

	NaOH-P	*HCl-P*	*IP*	*OP*	*TP*	*LOI*
NaOH-P	1					
HCl-P	-0.462**	1				
IP	-0.360*	0.921**	1			
OP	0.318	-0.508**	-0.546**	1		
TP	-0.345*	0.877**	0.786**	-0.254	1	
LOI	0.132	-0.327	-0.226	0.409*	-0.392*	1

Note: * and ** stand for difference at 0.01 and 0.05 levels respectively, n=35.

3.3 Discussion. Phosphorus species of the sediments began to change significantly nearly at the same layer (about 5 cm), with little fluctuating margin and unobvious vertical variation under 5 cm and marked increasing fluctuating margin above 5 cm, NaOH-P and OP increased fluctuatly, whereas TP, HCl-P and IP decreased fluctuatly. Results of dating showed[9] that 5 cm corresponding to 1995, little change in content of each phosphorus species indicating slight interference of human activities before 1995, whereas great change during 5-0 cm demonstrating strong interference of human activities since 1995 and the process of phosphorus pollution have also gradually intensified.

Studies of Ruban[3] show that content of NaOH-P and OP that measured by SMT sequential method can be roughly considered to be phosphorus that can potentially release, thus we can estimate the amount of bio-available phosphorus. As an important "secondary sources", part of NaOH-P and OP may activate with mineralization and decomposition of organic matter and change of the condition of oxidation-reduction[10]. According to results of dating [9], 5~0 cm corresponding to 1995~2007, the rapid increase in NaOH-P and OP indicating strong interference of human activities since the mid-1990s.

Nutrients of Dongping Lake mainly come from industrial wastewater, domestic sewage and surface runoff of Dawen basin and valleys of Dongping Lake, et al[11]. Dawen River input is the most important sources of nutrients, according to an estimation of PANG Qingjiang[11], input of Dawen River accounts for about 82.61% of the total phosphorus input, followed by valleys of Dongping Lake (14.47%). Studies have also showed that as chief source of phosphorus input of Dongping Lake, industrial waste water and domestic sewage discharge of Dawen River have increased significantly these years, which has resulted in severe water pollution. According to statistics, industrial and urban household wastewater discharge is about 1.64×10^9 t/a, COD is 6.42×10^4 t/a, and water quality of most pollutant discharging outlet sections is worse than Grade V during 1995~2004.

HCl-P originates from the clastic rock or local self-generating, and it can not easily be released into the overlying water and is considered bio-unavailable phosphorus and is free from anthropogenic pollution[12]. Content of HCl-P in the core sediments of Dongping Lake is very high (57.62%~69.82%), and HCl-P is one of the main species in the sediments. HCl-P was in stable state under 5 cm, reflecting the relatively stable natural input process and inertia of itself, whereas large fluctuation and a downward trend above 5 cm may indicating influence of human activities and change of the sedimentary environment.

Synchronous depositional research can fully understand the vertical distribution of phosphorus in the sediment and get a clearer understanding of the distribution of phosphorus[13]. Correlation analyses showed that TP is high correlated to the HCl-P and IP, indicating the increase of TP mainly from IP, and HCl-P is the controlling factor of IP and TP. HCl-P is the dominant component of TP, a slowly decreasing trend of TP in recent years mainly due to the reduced rate of HCl-P is greater than the increased rate of NaOH-P and OP. Besides, there were significant correlations between other phosphorus forms (except NaOH-P and OP), especially HCl-P and IP. When studying in the Northeastern United States sediments, Ostrofdy found that there was significant correlation between the organic matter and the OP[14]. Correlation analyses in this paper also showed that LOI have obvious correlation with OP and TP, and no relationships with NaOH-P, HCl-P and IP, indicating that the origin source of LOI is similar with OP and had little relation with NaOH-P, HCl-P and IP.

Conclusions

(1) Total phosphorus (TP) in the sediments of Dongping Lake averaged 548.36 mg/kg, in the range from 498.01 to 596.77 mg/kg and mainly composed of IP (69.26%-79.14%). The three main forms of phosphorus followed the order HCl-P＞OP＞NaOH-P, and HCl-P was the dominant component of TP. All the phosphorus forms had similar vertical distribution pattern under 5 cm (corresponding to 1995), with stable content and narrower fluctuation, and started to present remarkable change above 5 cm, an upward trend in NaOH-P, OP and a downward trend in HCl-P, IP and TP, which indicating that the distribution of phosphorus forms in the sediments was obviously affected by human activities from 1995.

(2) Correlation analyses showed that HCl-P was the main factor controlling TP and IP, there were significant correlations between TP and other phosphorus forms except OP, and correlations between other phosphorus species (except NaOH-P and OP) were obvious. LOI had obvious correlation with OP and TP, and no relationships with NaOH-P, HCl-P and IP.

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