Spatial Characteristic of Total Nitrogen and Organic Matter in Surface Sediments of Lake Shahu, China

Hongye He[1,a], Zhengwen Liu[1,2,b]

[1]Department of Ecology and Institute of Hydrobiology, Jinan University, Guangzhou 510632, China;

[2]State Key Laboratory of Lake Science and Environment, Nanjing Institute of Geography & Limnology, Chinese Academy of Sciences, Nanjing, 210008, China.

[a]851453491@qq.com, [b]zliu@niglas.ac.cn

Abstract

Nitrogen is one of the key limiting nutrients in lake ecosystems, and nutrient release from the sediments may delay the recovery of lakes from eutrophication. Lake Shahu, an urban lake located in Wuhan, Central China, has being eutrophic due to the excessive nutrient inputs from the city. In this paper we investigated the spatial distribution of total nitrogen and organic matter contents in surface sediments of Lake Shahu. The results showed that the average total nitrogen contents in the surface sediments ranged from 3640.12 to 9629.69 mg·kg^{-1} with a mean value of 7184.50 mg·kg^{-1}, and the average percentage of organic matter was 12.06%, ranging from 4.72% to 13.89%. Both total nitrogen and organic matter contents showed a high heterogeneity in spatial distribution, and higher values were observed in the eastern basin than the western basin in the lake. High contents of total nitrogen and organic matter suggested that measures for controlling nutrient release from the sediments may be needed to enhance the recovery of the lake following the reduction of the external nutrient loading.

Keywords

Eutrophication; Sediments; Total Nitrogen; Organic Matter.

1. Introduction

With the development of society and economy, lakes receive excessive external nutrient inputs, and eutrophication is becoming more and more serious in lakes worldwide including China [1, 2]. The sediments are the sink of pollutants in lakes. Nutrients such as nitrogen and phosphorus can be accumulated, forming a large pool in the sediments of lakes after a long-term pollution. Studies show that many lakes resist the efforts of reducing external nutrient loadings [3]. Further studies demonstrate that the nutrient release from the polluted sediments is responsible for the resistance of the lake ecosystems to the external loading reduction, and thus, measures on the controlling nutrient release from the sediments are recommended for lake restoration [3, 5].

Nitrogen is considered to be a key limiting factor for primary productivity of aquatic ecosystems, and an excessive loading from the catchment is responsible for lake eutrophication. Sediments are important sources and sinks of nitrogen in aquatic ecosystems [5, 6]. Due to the long-term pollution, a high nitrogen content can be found in lake sediments which may be released into lake water. Thus managing internal loading of nitrogen is needed to enhance the recovery of lakes after the reduction in external nitrogen inputs [2]. Organic matter is a complex mixture of carbohydrates, proteins, lipids and other organic components. It comes from organisms living in and around lakes or by basins and regions where lakes are located [7]. Organic matter can affect various physical and chemical process in sediment-water interface and thus the release of nitrogen and phosphorus from the sediments [8]. To a certain extent, sediment organic matter is also an important indicator of lake eutrophication [9].

Lake Shahu, with a surface area of 3.1 km^2, is located in the center of Wuhan, Hubei Province, central China and has multiple functions such as fishing and leisure tourism. In recent decades, an excessive nutrient input has resulted a serious problem of eutrophication in this lake. Many measures have planned to restore Lake Shahu including external nutrient loading reduction and sediment dredging. In this study, we analyzed the spatial distribution of total nitrogen (TN) and organic matter (OM) in order to evaluate the need of internal loading management for the restoration of Lake Shahu.

2. Material and Methods

There were 18 sampling points in total (Fig. 1). Among them, the sampling points S1~S7 were in the western lake basin and the sampling points S8~S18 were in the eastern lake basin. The sampling was carried out in December 2019. A hand corer with an inner diameter of 70 mm was used to collect the sediment samples. The upper 10 cm was taken as a surface sediment sample. All samples were sealed and brought back to the laboratory for analyses.

Samples were naturally dried to constant weight, mixed well, ground to a fine power with a grinder, and sieved with 100-mesh size. The determination of TN was done using persulfate digestion [10]. OM is determined by the loss on ignition (LOI) method [11]. The organic carbon (OC) is then calculated using the following equation:

OC=OM/1.724

The C/N ratio is then calculated using OC and TN [12].

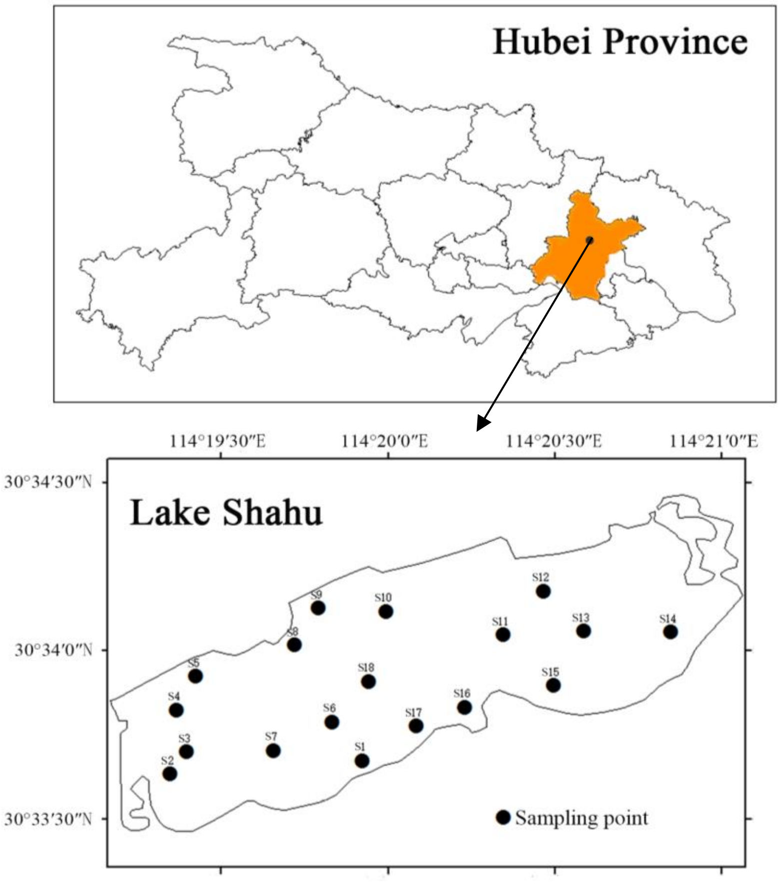

Fig. 1 Location of sampling points in Lake Shahu

3. Results and Discussion

3.1 Spatial Distributions of TN in the Surface Sediments

The TN contents of the sediments in Lake Shahu were shown in Fig. 2. The range of TN contents was 3640.12 to 9629.69 $mg \cdot kg^{-1}$, with an average of 7184.50 $mg \cdot kg^{-1}$. The highest TN content was in eastern lake basin (site S9), and the lowest value appeared at S1. According to the sediment quality evaluation guidelines formulated by the Ministry of Environment and Energy of Ontario, Canada in 1992, the level of TN content that can cause the severe effect is 4800 $mg \cdot kg^{-1}$ [13]. The average content of TN in the sediments of Lake Shahu was more than the severe effect level, thus the sediment is considered heavily polluted and likely to affect the health of sediment-dwelling organisms. The samples in the western lake basin had lower average TN compared to that in the eastern lake basin. This may be explained by the differences in historical pollutant loading. The high TN contents in the surface sediments of Lake Shahu suggest a possible high internal loading of nutrients resulted from the nutrient release from the sediments at certain physical-chemical and biological conditions [8].

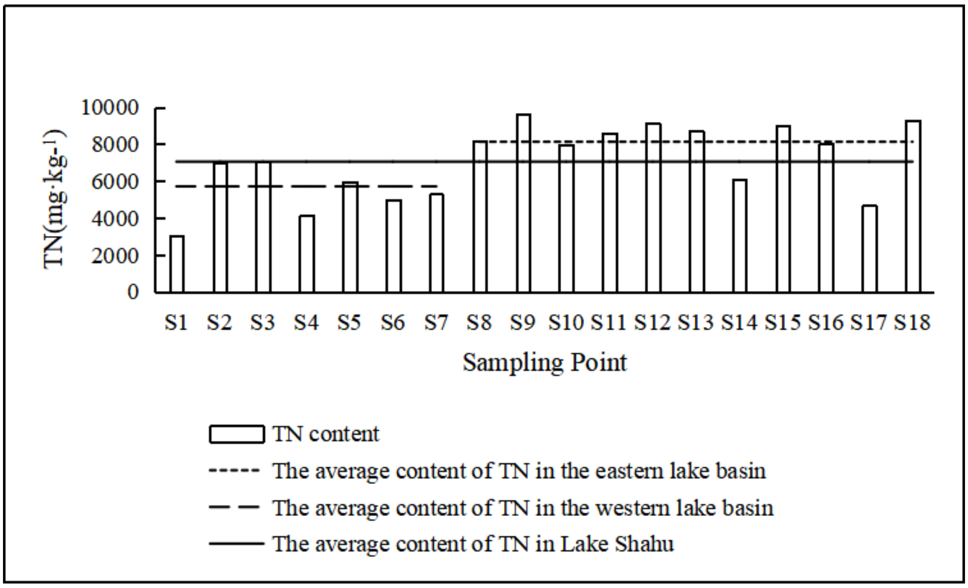

Fig. 2 Content and distribution of TN in the surface sediments of Lake Shahu

3.2 Spatial distributions of OM in surface sediments

Fig. 3 showed the spatial distribution of OM in the surface sediments of Lake Shahu. The contents of OM ranged from 4.72% to 13.89%, with an average value of 12.06%. The average OM content in the western lake basin was 11.58%, and the value in the eastern lake basin was 12.37%. The highest and lowest values of OM in the lake appeared in the western lake basin, with the highest value at S5 and the lowest value at S1. The OM of Lake Shahu was at a relatively high level, and the eastern lake basin may have a higher risk of nutrient release from the sediments than the western lake basin.

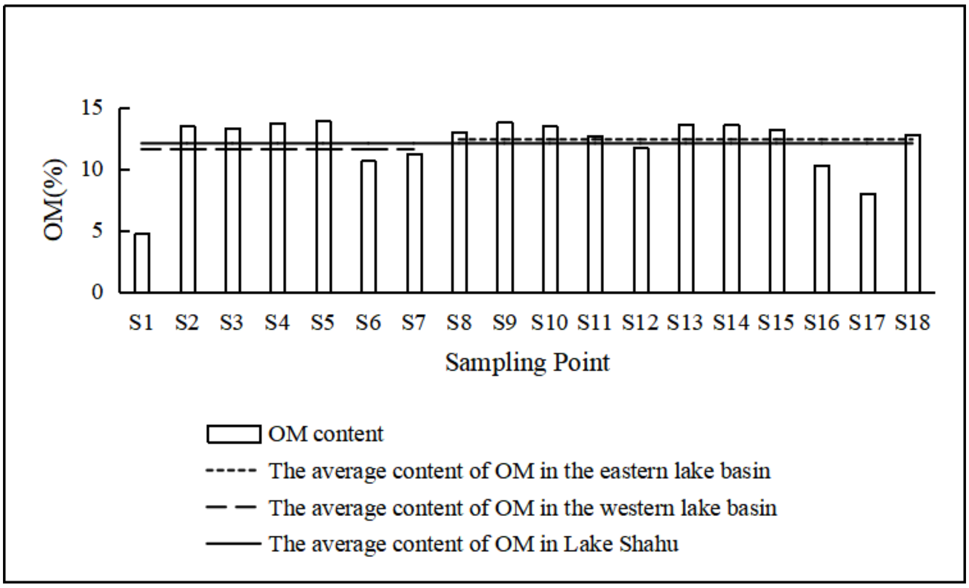

Fig. 3 Content and distribution of OM in the surface sediments of Lake Shahu

3.3 Spatial Distributions of C/N Ratio in the Surface Sediments

The C/N ratios of the surface sediment samples varied between 12.79 and 33.30, with the average of 17.98. The minimum value was observed at S12, and the maximum value was at S4 (Fig. 4). The average C/N ratio was 21.87 in the western lake basin, and 15.53 in the eastern lake basin.

To a certain extent, the sediment C/N ratio can be used as an important analysis method for the source of sediment organic matter [12, 14]. There can be a wide range in C/N ratios for various types of aquatic plants, but, in general, plankton have lower C/N ratios than periphyton and macrophytes [15]. Nonvascular aquatic plants have low C/N ratios, typically between 4 and 10, whereas vascular land plants, which contain cellulose, have C/N ratios of 20 and greater [10, 15]. The C/N ratio of the sediments that receive terrestrial organic matter is higher than that of the sediments that receive algae [16]. The lower C/N ratios indicate a higher tropic state in the eastern lake basin than that in the western lake basin.

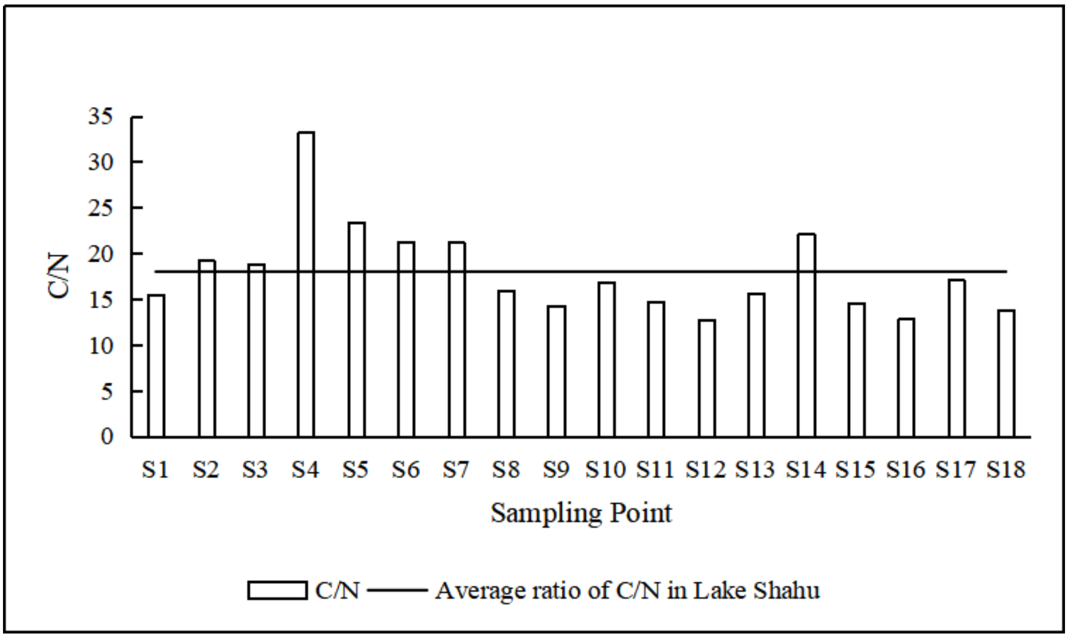

Fig. 4 The C/N ratios of surface sediments in Lake Shahu

4. Conclusion

This study showed that the TN and OM contents in the surface sediments of Lake Shahu were very high. A high heterogeneity was found in the spatial distribution of TN and OM, and higher average values of both TN and OM were observed in the eastern lake basin than that in the western lake basin. Therefore, effective internal nutrient loading managements may be needed following the reduction in external nutrient loading in order to enhance the recovery of Lake Shahu, especially in the eastern lake basin.

Acknowledgements

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