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Original Research

Spatial Distribution and Seasonal Variation of Heavy Metals in Water and Sediments of Taihu Lake

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Abstract

Heavy metal distribution in aquatic ecosystems can be influenced by a variety of factors. In this study, the spatial distribution and seasonal variation of heavy metals (Cd, Ni, Cu, Zn, Cr, and Pb) in lake water and sediments of different lake zones of a large, shallow, eutrophic freshwater lake, Taihu Lake, were investigated. Metal concentrations in the river water, bloom assemblages, and macrophyte materials were also determined. The results demonstrated that metal distribution in Taihu Lake showed distinct patterns in different seasons. Metal concentrations in rivers around Taihu Lake showed some peaks that may contribute to the elevated metal concentrations in lake water and sediments. However, the metal concentrations in the river water did not fluctuate significantly with months (March, July, and December). The dissolved metal concentrations in the phytoplankton-dominated zone of the lake were significantly higher than those in the macrophyte-dominated lake zone in summer, which could be attributed to the different dominated primary producers in the two lake zones. Statistical analysis results demonstrated that the dissolved metal concentrations were positively correlated with water turbidity for all metals in July. However, the positive correlations disappeared for most metals of March and December samples. The results of this study could provide useful information for further understanding of the transportation and fates of heavy metals in different freshwater lake ecosystems.

Keywords: heavy metals, freshwater lake, river, water, sediments

Introduction

Anthropogenic activities such as the discharge of industrial effluents and domestic wastewater contribute mostly to the heavy metal pollution in aquatic environments, which possesses potential risks to both aquatic organisms and human beings. Biotic and abiotic factors could affect the transport and fate of metals in aquatic ecosystems [1]. Season and ecological type also could influence metal distribution in aquatic ecosystems [2-3]. Spatial distributions of heavy metals in different aquatic ecosystems, including marine and freshwater sediments, have been documented in previous studies [4-5]. However, few studies explained the seasonal variation of heavy metals in water column and sediments of a freshwater lake ecosystem.

Taihu Lake is one of the largest freshwater lakes in China. It is an important source of drinking water for the residents, and an important resource for shipping, freshwater fisheries, and aquaculture. As a result of increasing anthropogenic activities over the past decades, Taihu Lake

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was heavily contaminated and its water quality deteriorated rapidly. There were more than one hundred rivers around Taihu Lake, which received a large amount of untreated and partially treated industrial wastewater, household effluent, and agricultural run-off from the surrounding areas. These discharges were the main pollution sources of the lake [6]. Metal pollution and eutrophication are two serious environmental problems of Taihu Lake [7]. A number of previous studies have examined the nutrient distribution in Taihu Lake [8, 9]; however, few studies have systematically examined the spatial distribution and seasonal variation of heavy metals in the water column and sediment of this lake. Furthermore, the exogenous pollutant inputs around Taihu Lake have been cut down by the Chinese government since 2007 [10]. Therefore, the influence of exogenous metals on water quality needs to be reevaluated.

There are two distinct ecological regions in Taihu Lake: the phytoplankton- and macrophyte-dominated lake zones. Cyanobacteria were the major primary producer in the phytoplankton-dominated lake zone in recent years [11]. Cyanobacterial blooms occurred in this lake zone from the 1980s and became more intensive in the last two decades. The macrophyte-dominated zone, in contrast, was characterized by a variety of macrophytes, and the floating leaf and submerged macrophytes covered approximately 97% of its total area [7]. Previous studies reported that heavy metal concentrations were enriched in the water and sediments of the phytoplankton-dominated lake zone [12]. Cyanobacteria could adsorb heavy metals, and the metals would be released from the cyanobacterial cells after their decomposition [13-15]. Macrophytes in the aquatic ecosystems could also accumulate heavy metals substantially in summer [16]. However, the metals would also be released to the water column after the decomposition of macrophytes in winter. Therefore, it is supposed that metal distribution in the water column and sediments of the two distinct lake zones may be different.

In this study, heavy metal (Cd, Ni, Cu, Zn, Cr, and Pb) concentrations in lake water and sediments of different lake zones of Taihu Lake were investigated in March, July, and December. Metal concentrations in the water of rivers connected to Taihu Lake were also measured. Additionally, metal concentrations in bloom assemblages and macrophyte materials also were determined. The aims of this study were:

(1) to investigate the spatial distribution and seasonal variation of heavy metals in Taihu Lake
(2) to explore the important environmental factors that influence the metal distribution in the lake.

Materials and Methods

Study Area

Taihu Lake (30º55′-31º33′ N, 119º55′-120º36′ E) is located in the southeastern part of the Yangtze Delta, China. The surface area and mean depth of Taihu Lake are 2,338 km^2 and 1.89 m, respectively, and the average hydraulic retention time is approximately 270 days [17]. Meiliang Bay and Xukou Bay are two distinct ecological zones in Taihu Lake (Fig. 1). Meiliang Bay is the phytoplankton-dominated lake zone located in the northern part of the lake. Serious cyanobacterial blooms have increased in frequency and intensity in recent years in this area [18]. Xukou Bay is a macrophyte-dominated area in the southeastern part of the lake. Most of Xukou Bay is covered by aquatic vegetation [19].

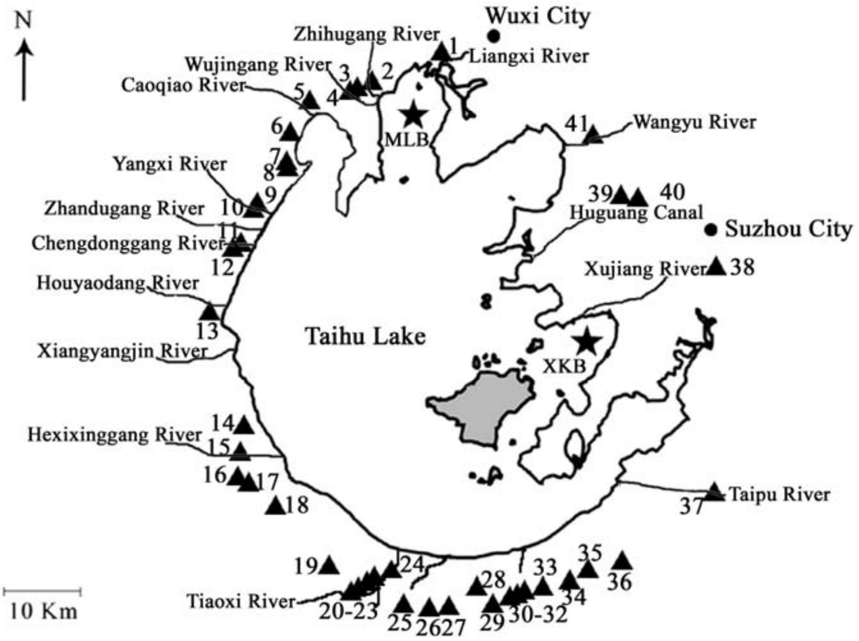

Fig. 1. Sampling sites in Taihu Lake. There were totally 60 sampling sites distributed in Taihu Lake: 11 sites at Meiliang Bay (MLB, ★), 8 sites at Xukou Bay (XKB, ★), and 41 sites (▲) at surrounding rivers.

Water and sediment samples were collected from different zones of Taihu Lake in March, July, and December 2009 and 2010. There were 60 sampling sites total distributed in Taihu Lake: 11 sites at Meiliang Bay, 8 at Xukou Bay, and 41 at the rivers around Taihu Lake (Fig. 1). Sediment samples were collected only at Meiliang Bay and Xukou Bay. Cyanobacterial assemblages and the submerged macrophyte materials were collected in summer at Meiliang Bay and Xukou Bay, respectively.

Sample Collection and Preparation

Water samples were collected at sampling stations using a plastic water sampler at 50 cm depth. At each site, three subsamples of water were collected and mixed to ensure that the sample was representative for this site. Water samples were stored in acid-washed polyethylene bottles and transported to the laboratory immediately. The YSI-6200 multiparameter model (YSI Inc., USA) was employed to measure the *in situ* physicochemical parameters, including water temperature, pH, and turbidity. Secchi depth was measured with a secchi disk. Water samples were filtered through 0.45 µm Millipore filters and then acidified with superpure HNO_3 (1%) for dissolved metal analysis. Filtered water samples were analyzed for dissolved organic carbon (DOC) with TOC-5000A (Shimadzu, Japan). The cell numbers of the bloom-forming *Microcystis* sp. were counted under the microscope after fixing with Lugol's iodine solution.

Surface sediment samples were collected using a polypropylene column sampler. Three replicated sediment samples were collected at each site and homogenized. The samples were then freeze-dried (Labconco, Cole-Parmer Instrument Co., USA) at -70ºC for 7 days. Large debris and fragments of shells were removed from the sediments before grinding. All the sediment samples were then ground in an agate mortar and sieved with a 0.1-mm nylon sieve. Cyanobacterial assemblages were collected at Meiliang Bay, where a large amount of cyanobacterial cells were assembled on the water surface. The collected cells were rinsed with ultra-pure water (Milli-Q, 18.2 $M\Omega\cdot cm^{-1}$). Three replicates of *Potamogeton malaionus*, *Vallisneria natans*, and *Ceratophyllum demersum* were collected and the leaves were used for metal analysis.

Metal Measurement and Accuracy Control

Sediment samples were digested following the method described by Yu et al. [20]. Briefly, approximately 0.2 g of sediment samples were added into the digestion vessels with 2 mL of HNO_3 (69%, superpure) and 6 mL of HCl (35%, superpure). The vessels were gently shaken and then pre-digested at room temperature for 2 h. Then the vessels were put in a microwave oven (Speedwave® four Microwave Digestion System, Germany) for digestion using the EPA 3051 protocol. The obtained mixtures were diluted to specified volumes with ultra-pure water. An international certificated standard reference sediment (IAEA-158) and reagent blanks were digested following the same protocol to control the accuracy. The recovery percentages for the analyzed metals in sediment reference materials were within 85-110%. The digestion method described by Ho et al. [21] was employed to analyze the metal concentrations in bloom assemblage and macrophyte samples.

Inductively coupled plasma mass spectrometry (ICP-MS, Perkin-Elmer, Elan 9000) was used to measure the concentrations of Cd, Ni, Cu, Zn, Cr, and Pb. The detection limits were 0.005, 0.03, 0.02, 0.05, 0.02, and 0.02 µg/L for Cd, Ni, Cu, Zn, Cr, and Pb, respectively. All specimens were run in batches that included blanks, certified reference materials, and the samples. A standard for all examined metals was checked every 20 specimens to ensure analytical accuracy.

Statistical Analysis

All the statistical analyses were conducted using the SPSS software package (version 13.0, SPSS Inc.). T-test was carried out to analyze the significance of differences between samples. Correlation between metal concentrations and water physicochemical parameters were analyzed. Statistical significance was acceptable at $p < 0.05$.

Results

Physicochemical Characteristics of Water Collected from Different Lake Zones

Physicochemical parameters of the lake water sampled from different lake zones and different seasons are shown in Table 1. The pH values were comparable between the two lake zones in each month ($p > 0.05$). Water temperature showed the highest values in summer (July) and the lowest values in winter (December). The dissolved organic carbon (DOC) concentrations of water samples collected in March were comparable between the two lake zones. For July samples, the DOC concentrations of Meiliang Bay were significantly higher than those of Xukou Bay ($p < 0.05$). Inversely, the DOC concentrations of Xukou Bay were significantly higher than those of Meiliang Bay in December ($p < 0.05$). Water turbidity of Xukou Bay was significantly higher than that of Meiliang Bay in March ($p < 0.05$). In July, water turbidity of Xukou Bay decreased dramatically, which was significantly lower than that of Meiliang Bay ($p < 0.05$). There was no significant difference of water turbidity between the two lake zones in December ($p > 0.05$). Correspondingly, secchi depth in Meiliang Bay was significantly higher than that of Xukou Bay in March ($p < 0.05$), whereas the values became comparable in December. The cell densities of cyanobacteria in different zones of Taihu Lake were also measured. Results indicated that *Microcystis* sp. were the dominant species, accounting for more than 90% of the total cell number of the bloom assemblages, and the cell numbers of *Microcystis* sp. in Meiliang Bay were significantly higher than those of Xukou Bay in July ($p < 0.05$).

Table 1. Water physicochemical parameters in different lake zones of Taihu Lake. Values are means±SD (N ≥ 3).

Parameters[a]	Meiliang Bay (March)	Xukou Bay (March)	Meiliang Bay (July)	Xukou Bay (July)	Meiliang Bay (December)	Xukou Bay (December)
pH	8.32±0.20	8.39±0.11	8.90±0.50	8.69±0.22	8.13±0.28	8.06±0.06
Temperature (ºC)	12.88±1.38	11.59±0.22	31.44±1.09	30.18±0.43	7.96±0.79	8.01±0.13
DOC (mg/L)	13.47±8.06	18.75±12.06	16.34±13.62*	4.40±1.79	14.07±4.07	29.80±5.26*
Turbidity (NTU)	23.85±9.12	90.20±26.92*	31.23±11.93*	0.91±0.35	48.94±29.96	89.98±42.36
Secchi depth (cm)	41.67±13.49*	18.75±4.20	24.50[b]	91.00[b]	29.3±8.4*	15.9±5.6

[a] DOC – dissolved organic carbon; NTU – nephelometric turbidity units.

[b] Only one value was available.

*Values of one lake zone were significantly higher than those of the other lake zone within the same month ($p < 0.05$).

Table 2. Dissolved metal concentrations (μg/L) in lake water collected from different lake zones of Taihu Lake in different months. Values are means±SD (N ≥ 8).

Metals	Meiliang Bay (March)	Xukou Bay (March)	Meiliang Bay (July)	Xukou Bay (July)	Meiliang Bay (December)	Xukou Bay (December)	CNEQS[a]	WHO[b]	CC[c]
Cd	0.016±0.005	0.012±0.002	0.024±0.009*	0.009±0.004	0.019±0.003*	0.011±0.004	1	3	0.25
Ni	5.20±2.58*	1.99±0.15	2.66±0.53*	0.83±0.22	3.57±1.65*	1.50±0.43	/	20	52
Cu	3.14±0.79*	1.86±0.22	3.45±0.94*	1.31±0.17	3.04±0.45	2.23±0.63	10	2000	9
Zn	3.77±1.69	2.98±1.06	5.47±2.37*	2.32±0.35	9.62±0.40	9.86±1.13	50	/	120
Cr	1.58±0.39	1.29±0.27	2.27±0.51*	1.50±0.11	0.95±0.30	0.87±0.30	10	50	85
Pb	0.06±0.04	0.07±0.05	1.05±0.66*	0.18±0.05	0.39±0.08	0.77±0.20*	10	10	2.5

[a] The first class category of CNEQS (Chinese National Environmental Quality Standards) for Surface Water.

[b] WHO (World Health Organization) guideline for drinking water.

[c] CC: The chronic criteria of freshwater quality for aquatic life [24].

*Metal concentrations of one lake zone were significantly higher than those of the other lake zone within the same month ($p < 0.05$).

Dissolved Metal Concentrations in Taihu Lake

The concentrations of dissolved metals (Cd, Ni, Cu, Zn, Cr, and Pb) in lake water of different lake zones of Taihu Lake in March, July, and December are shown in Table 2. For water samples collected in March, concentrations of the dissolved Ni and Cu in Meiliang Bay were significantly higher than those in Xukou Bay ($p < 0.05$). Additionally, concentrations of all the examined metals in Meiliang Bay were significantly higher than those in Xukou Bay for July samples ($p < 0.05$). The average concentrations of Cd, Ni, Cu, Zn, and Pb in Meiliang Bay were more than 2 times higher than those in Xukou Bay in July. For December samples, the average concentrations of Cd and Ni in Meiliang Bay were more than 1.5 times higher than those in Xukou Bay ($p < 0.05$). Inversely, the Pb concentrations in Xukou Bay were approximately 2 times higher than those in Meiliang Bay in December ($p < 0.05$), which was quite different from the other metals and the data obtained in July.

Compared with several kinds of water quality standards (Table 2), the metal concentrations in the water of Taihu Lake were far below the first class category of the Chinese National Environmental Quality Standards (CNEQS) for surface water [22], the World Health Organization (WHO) guidelines for drinking water [23], and the chronic criteria of freshwater quality for aquatic life [24].

Significant differences were observed for water physicochemical parameters (DOC and turbidity) and metal concentrations between different lake zones. Therefore, the relationship between water characteristics (DOC and turbidity) and heavy metal concentrations were analyzed with statistical method (Table 3). The results demonstrated that the Cd, Ni, Cu, and Cr concentrations were negatively correlated with water turbidity in March ($p < 0.05$). In contrast, positive correlations were observed between water turbidity and all the examined metals (Cd, Ni, Cu, Zn, Cr, and Pb) in July. At the same time, the Cd and Ni were positively correlated with DOC concentrations ($p < 0.05$). For samples collected in December, the Cd, Ni, and Cu concentrations were negatively correlated with the DOC concentrations. For all the metals investigated in this study, only the Pb showed consistently positive correlations with water turbidity in different months. With the elevated water turbidity, the dissolved Pb concentrations increased linearly for all samples.

Table 3. Correlation analysis between dissolved metal concentrations and water physicochemical parameters (water turbidity and dissolved organic carbon (DOC)) in different months.

Metals	Turbidity (March)	DOC (March)	Turbidity (July)	DOC (July)	Turbidity (December)	DOC (December)
Cd	-0.59*	-0.26	0.71*	0.57*	-0.22	-0.60*
Ni	-0.61*	-0.29	0.96**	0.58*	-0.46	-0.71**
Cu	-0.72**	-0.38	0.94**	0.46	-0.11	-0.60*
Zn	-0.25	-0.32	0.88**	0.49	0.62**	0.18
Cr	-0.57*	-0.33	0.89**	0.35	0.22	-0.22
Pb	0.09	-0.10	0.94**	0.31	0.94**	0.86**

* Correlation is significant at the $p < 0.05$ level.

** Correlation is significant at the $p < 0.01$ level.

These results further suggested that the sediment suspension may affect the concentrations of specific metals in lake water.

Taihu Lake receives water from a series of rivers around it. In order to examine whether the elevated metal concentrations in different lake zones were attributed to the input water, metal concentrations of 41 water samples collected in the rivers around Taihu Lake were also measured and the results are shown in Fig. 2. Generally, the distribution patterns of metals were quite similar for samples collected in different months (March, July, and December), suggesting the river input may not be the main reason for the significant variation of metal concentrations in different lake zones and different seasons in Taihu Lake. For the rivers located on northern Taihu Lake (sites from 1 to 8), fluctuations were observed in the concentrations of Ni, Cu, Zn, and Cr, while the concentrations of Cd and Pb did not show remarkable variations. For the rivers located on the western part of the lake (sites from 9 to 18), Cd and Pb concentrations exhibited some peaks, whereas the concentrations of Ni, Cu, Zn, and Cr remained steady. For the southern rivers (sites from 19 to 36), the Ni, Cr, and Pb concentrations showed some variations, while Cd, Cu, and Zn concentrations kept steady. The Cd, Ni, and Zn concentrations in rivers located in the eastern part of the lake (sites from 37 to 41) showed some fluctuations, whereas concentrations of other metals kept stable.

Metal Concentrations in the Sediments, Bloom Assemblages, and Macrophytes

The average metal concentrations in sediments, bloom assemblages, and macrophytes of Taihu Lake are shown in Table 4. The seasonal variation of metal concentrations in the sediments differed from those of the lake water. The Ni and Cr concentrations in the sediments of Meiliang Bay were significantly higher than those of Xukou Bay in March ($p < 0.05$). In contrast, concentrations of all the examined metals were comparable between sediment samples of Meiliang Bay and Xukou Bay in July ($p > 0.05$). However, concentrations of all the examined metals

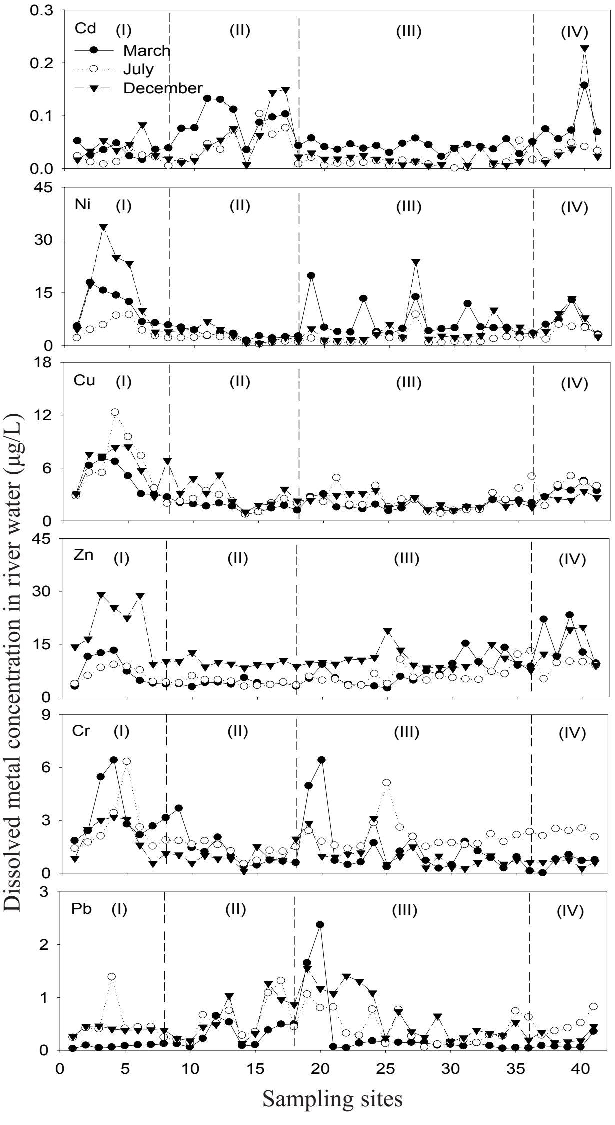

Fig. 2. Dissolved metal concentrations (μg/L) in rivers connected to Taihu Lake. Rivers locate in the northern (I, sites from 1 to 8), western (II, sites from 9 to 18), southern (III, sites from 19 to 36), and eastern (IV, sites from 37 to 41) parts of Taihu Lake. Water samples were collected in March (●), July (○), and December (▼).

Table 4. Metal concentrations (μg/g) in the sediments, cyanobacterial assemblages, and macrophytes from different lake zones of Taihu Lake. Values are means±SD ($N \geq 3$).

Metals	Meiliang Bay (March)	Xukou Bay (March)	Meiliang Bay (July)	Xukou Bay (July)	Meiliang Bay (December)	Xukou Bay (December)	Cyanobacteria[a] (July)	Macrophytes[b] (July)
Cd	0.23±0.11	0.18±0.08	0.12±0.06	0.08±0.04	0.12±0.07*	0.06±0.04	2.52±0.07	0.32±0.17
Ni	45.38±17.00*	21.10±3.83	24.59±3.53	24.28±3.15	23.02±5.92*	17.33±3.68	20.60±6.27	3.07±1.75
Cu	47.09±25.65	19.50±2.88	20.45±4.23	18.52±2.40	20.96±5.35*	14.54±2.28	9.47±1.95	7.71±3.29
Zn	73.66±40.32	31.37±5.64	49.38±10.49	45.22±8.63	50.26±20.47*	30.61±7.16	9.67±3.14	42.39±23.16
Cr	57.70±21.20*	31.91±5.67	71.88±11.29	70.08±14.99	60.50±10.28*	49.35±12.59	3.67±1.37	2.95±1.24
Pb	22.16±4.50	18.03±4.81	21.83±4.41	21.55±6.81	20.81±5.43*	15.89±2.32	1.55±0.63	1.37±0.92

[a] The cyanobacterial assemblages were collected from Meiliang Bay.

[b] The macrophytes, including *Potamogeton malaionus*, *Vallisneria natans*, and *Ceratophyllum demersum,* were collected from Xukou Bay.

*Metal concentrations of one lake zone were significantly higher than those of the other lake zone in the same month ($p < 0.05$).

(Cd, Ni, Cu, Zn, Cr, and Pb) in the sediments of Meiliang Bay were significantly higher than those of Xukou Bay in December ($p < 0.05$).

The Cd concentrations in the bloom-forming cyanobacterial assemblages were about 20 times higher than those in the sediments of Meiliang Bay ($p < 0.05$) (Table 4), which might explain the higher Cd concentrations in the sediments of Meiliang Bay compared with those of Xukou Bay. In contrast, the Cu, Zn, Cr, and Pb concentrations in the sediments were significantly higher than those in the bloom assemblages ($p < 0.05$), and the Ni concentrations in the bloom assemblages were comparable to those in the sediments, suggesting that the bloom assemblages may contribute less to the enhanced metal (Ni, Cu, Zn, Cr, and Pb) concentrations in the sediments. The Ni, Cu, Cr, and Pb concentrations in the macrophytes of Xukou Bay were significantly lower than those in the sediments of different lake zones ($p < 0.05$), while the Cd and Zn concentrations were comparable between the sediments and macrophytes. Therefore, it was suggested that the aquatic macrophytes may also contribute less to the enhanced metal concentrations in the sediments.

Discussion

Generally, the dissolved metal concentrations in Taihu Lake measured in this study were commonly within the ranges detected in the Yangtze River [25]. The lake water and sediments of Taihu Lake were found to be heavily contaminated by heavy metals over the last decade [26]. Previous studies demonstrated that the concentrations of Cu, Mn, Ni, Pb, and Zn in surface sediments of northern Taihu Lake were higher than those of the other lake zones [7, 12]. Anthropogenic discharges were considered to be the main reason for the elevated metal concentrations in the sediments of northern Taihu Lake. However, the exogenous pollutant inputs around Taihu Lake have been reduced by the Chinese government since 2007 [10]. In the present study, metal concentrations in the water of rivers around Taihu Lake (such as Ni, Cu, Zn, and Cr in the northern rivers, Cd in the western rivers, and Cr and Pb in the southern rivers) showed some peaks (Fig. 2), suggesting that the exogenous metals from rivers may play important roles in the elevated metal concentrations in lake water and sediments of Taihu Lake. However, the results also demonstrated that the metal concentrations in river water around Taihu Lake did not change significantly with months (March, July, and December) (Fig. 2). Therefore, the seasonal variation of metal concentrations in lake water from different lake zones could not be attributed to the exogenous inputs from rivers. It is implied that other factors, such as the cyanobacterial blooms and macrophytes, may affect the metal distribution in different lake zones of the lake.

Taihu Lake is located in the eastern part of China, where the southeast monsoon is the dominate wind direction in summer. Cyanobacterial blooms have occurred in Taihu Lake intensively in recent decades. The cyanobacterial cells in surface water would be blown by wind from the southeastern to the northern or northwestern parts of the lake, resulting in the accumulation of cyanobacterial assemblages in Meiliang Bay (Fig. 1) [27, 28]. Previous studies demonstrated that concentrations of dissolved Cd, Ni, and Zn in lake water decreased during the spring water bloom, and these metals were remobilized after the bloom declined [29]. Additionally, the sinking cyanobacterial cell detritus would also adsorb metals from the water column into the sediments [30], leading to the increase of metal concentrations in the sediments.

In the present study, the occurrence of intensive cyanobacterial blooms was assumed to influence metal distribution and cycling in aquatic ecosystems [31]. Cyanobacterial cells could uptake a large amount of metals from lake water during the growth process [32], and the metals in the cells would be transported to the phytoplankton-dominated zones of Taihu Lake by wind [33]. After the quick decomposition of the cells, the intracellular metals would be released from the declined cyanobacterial cells and transported into the lake water, resulting in an increase of dissolved metal concentrations [34]. In contrast, Xukou Bay, located in the southeastern part of Taihu Lake, was mostly covered by a variety of submerged macrophytes other than cyanobacterial cells [35]. Macrophytes in the aquatic ecosystems could reduce water flow velocity and stabilize sediments, which would accumulate heavy metals in summer and then reduce the metal concentrations in lake water [16]. In the present study, the dissolved metal concentrations in the phytoplankton-dominated zone (Meiliang Bay) were significantly higher than those in the macrophyte-dominated lake zone (Xukou Bay) in summer (Table 2), which could be attributed to the different dominated primary producers in the two lake zones. Therefore, the spatial distribution of dissolved metal concentrations in lake water could be influenced by cyanobacterial blooms or macrophytes.

In winter or spring, most of the macrophytes at Xukou Bay decayed and the metals in the macrophyte materials were released into the lake water, which may lead to the enhanced dissolved metal concentrations in Xukou Bay (Table 2). The decayed macrophytes and strong wind in winter or spring would result in the resuspension of sediment particles, which was confirmed by the dramatically increased water turbidity of Xukou Bay in winter and spring (Table 1). Resuspended particles have profound influences on metal distribution in aquatic environments [1]. Some studies found that sediment resuspension could enhance the release of metals to the dissolved phase [36]. Other studies have suggested that suspended solids could reduce the dissolved metal concentrations [37]. In the present study, the dissolved metal concentrations were positively correlated with water turbidity in July ($p < 0.05$ for all metals). However, the positive correlations disappeared for most metals of March and December samples (Table 3). It is suggested that other complicated factors may affect the correlations between metal concentrations and water turbidity. Additionally, Cr and Pb concentrations in the sediments were more than 10-fold higher than those in the bloom assemblages and macrophytes (Table 4), suggesting that sediment resuspension (increased water turbidity) may play an important role in the elevated Cr and Pb concentrations in water columns.

Conclusions

In conclusion, metal concentrations in rivers around Taihu Lake showed some peaks that may contribute to the elevated metal concentrations in lake water and sediments of corresponding lake zones. However, the metal concentrations in river water did not fluctuate significantly with months (March, July, and December), suggesting that other factors may affect the metal distribution in different lake zones. The dissolved metal concentrations in the phytoplankton-dominated zone (Meiliang Bay) were significantly higher than those in the macrophyte-dominated lake zone (Xukou Bay) in summer, which could be attributed to the different dominated primary producers in the two lake zones. The dissolved metal concentrations were positively correlated with water turbidity in July. However, the positive correlations disappeared for most metals of March and December samples, suggesting that other complicated factors may affect the correlations between metal concentrations and water turbidity. The results obtained in this study could provide useful information for further understanding the transportation and fates of heavy metals in different freshwater lake ecosystems.

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