RETRACTED ARTICLE: Pollution characteristics and risk assessment of heavy metals in the surface sediments of Dongting Lake water system during normal water period

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ABSTRACT
In order to study the characteristics and ecological risks of heavy metal pollution in Dongting Lake, 24 sediment cores were collected in August, 2017. The content characteristics and the pollution status of heavy metals in the study area were analyzed by the method of Igeo, RI and mPEC-Q, and the interrelation and source of heavy metals were evaluated by CA and PCA. The results showed that the concentrations of heavy metals in the surface sediments followed the order of Cr > Pb > Cu > As > Cd > Hg, and the contents of Hg, Cr, Cd, Pb, Cu were 7.0, 2.0, 9.3, 2.2, 2.3 times greater than the background values, respectively. The results using the geo-accumulation index and the potential ecological risk assessment indicated that Cd and Hg were considered as the dominant pollutants. The RI values followed the order of Cd > Hg > Cu > Pb > As > Cr and the mean value of mPEC-Q was 0.43, indicating that the sediments in all of the sampling sites had a 15%-29% probability of toxicity. Source analysis showed that As, Pb, Cd and Cu were homologous and mainly came from the industrial wastewater of the “Four-rivers” basin.

Research background
The Yangtze Economic Belt, which accounts for more than 40% of China’s population and regional GDP, is the center and vitality of China’s economy. General Secretary Xi Jinping pointed out that the Yangtze River is an important support for the development of the Chinese nation. It is necessary to put the restoration of the ecological environment of the Yangtze River in an overwhelming position to promote mass environmental protection, not to carry out large-scale development and strive to build the Yangtze Economic Belt into a more ecologically beautiful golden economic zone (Xi, 2018). However, the Yangtze River is “sick” seriously. To cure the “Sickness”, it is necessary to solve the environment overdraft problem of the Yangtze River progressively. The high density distribution of heavy chemical industry along the Yangtze River has been an agglomeration area for China’s heavy chemical industry for a long time, especially for the Dongting Lake (28°44’~29°35’ N, 111°53’~113°05’E). As one of the “two kidneys” of the Yangtze River, a large number of heavy metal pollutants caused by upstream metal mining flow into the lake area (Mao et al., 2013), combined with the agricultural wastewater and domestic sewage admitted annually from the surrounding cities are increasingly aggravating the lake’s heavy metal pollution problem (Li et al., 2013; Wang et al., 2018), and the environmental problem of East Dongting Lake is more serious as a confluence terminal point. Therefore, in order to implement environmental protection of the Yangtze River and to cure the “heavy metal sickness” of Dongting Lake, it is of great significance to “diagnose” the sediments pollution of Dongting Lake water system.

This paper aims to research the distribution characteristics of heavy metal pollution in surface sediments from the Dongting Lake water system during normal water period and evaluate the risks of pollution. As a key research object for a long time (El-Amier et al., 2017; Islam et al., 2018; Lin et al., 2016; Qian et al., 2014; Tang et al., 2010), the heavy metals in sediments can better reveal the status of water pollution and the evolution of aquatic ecological-environment. Benson (Benson et al., 2017) did research into the degree and ecological risks of heavy metal pollution in sediments along the Niger Delta, revealing that the sediments in this region were polluted by Cd and Pb, and there were high ecological risks in each ecosystem. Gray (Gray et al., 2013) did research into the Ballinger Lake, finding that the content of Hg and Pb increased by three orders of magnitude over the past 100 years when the Tacoma Metallurgical Refinery was operated, but the content of the two heavy metals decreased by 55%~75% after being shut down, it was pointed out that the metal refinery industry was the main source of Hg and Pb. Wyzga (Wyżga & Ciszewski,
2010) conducted research on the content distribution of the heavy metals in sediments of the Vistula River under different hydraulic characteristic conditions, the results showing that the heavy metal concentration increased with the increase of the width of the river channel, that there was higher content of heavy metals in the river channel edge with wider floodplains, and that the heavy metals might be re-released in the future when the river banks were eroded. Islam (Islam et al., 2015) studied 6 heavy metals in the surface water and sediments in the Korotaa River, an urban river in Bangladesh, finding that the heavy metal concentration in the surface water was much higher than the drinking water range in safe, and the sediment quality was also steadily deteriorated. They pointed out that pollution had posed a serious threat to the surrounding biota and residents. In China, the content of heavy metals in sediments in the Chao Lake, Taihu Lake, Poyang Lake, Three Gorges Reservoir, Bohai Bay and Yangtze River Basin is higher than background level and has raised considerable concern (Bian et al., 2017; Bing et al., 2016; Feng et al., 2018; Wu et al., 2014; Xin et al., 2016). Yu et al. (2011) pointed out that the heavy metal pollution of sediment had confronted nearly 80% of the global population with issues of water quality safety under the influence of human activities. Therefore, it is of far-reaching significance to research the distribution characteristics of heavy metal pollution in sediments.

At present, research on the sediments in heavy metal pollution in Dongting Lake, such as study on distribution characteristics, ecological risks, changing trends, possible pollution sources and the relationship between the inflowing rivers with the lake has been carried out to some extend (Guo et al., 2016; Xie et al., 2017; Yao et al., 2006; Zhang et al., 2015), but there are few systematic studies giving equal consideration to those factors. In view of the regional pollution characteristics, and the results of previous research, this paper chose 6 most typical heavy metals (Hg, As, Cr, Cd, Pb and Cu) in the Dongting Lake water system as key study objects to make a multi-method evaluation of the 24 sampling points in the study region and analyze their possible resources in order to provide a theoretical reference for the sustainable development of the Yangtze Economic Belt and the ecological protection sphere around the Dongting Lake by making a “diagnosis” of the Dongting Lake water system.

Materials and methods

Sampling point selection and sample collection

The twenty-four sampling points were selected during normal water period in accordance with the zoning of the Dongting Lake and the distribution of outflowing and inflowing rivers (Figure 1), which were divided into three categories. The first categories locate in the main stream of the Yangtze river(C1,C23,C24) and the second locate in the inflowing rivers, including the “Four Estuaries” (C2-C5), the “Four Rivers” (C6-C9), the Miluo River (C10), Xinqiang River (C11), and the other estuaries (C12-C14). The third categories is the lake region including typical enclosed lake (Datong Lake) (C15), the West, South and East Dongting Lake (C16-C18), the dividing points (C19-C22). All the sampling sections were localized by portable GPS. In August 2017, Pedersen bottom sampler was used to collect samples from the surface sediments of 0–10 cm at the above sampling points, which were frozen immediately after being taken back to the laboratory.

Sample processing and analysis

The surface sediment samples were vacuum-frozen-dried for 4 h at −40°C, and then put in a dryer after purification, grinding and sieving (100 meshes) after sample treatment. The content of As and Hg in the samples was determined with an atomic fluorescence spectrophotometer (PF52, China), while the content of Cr, Cd, Pb and Cu was determined with an inductively coupled plasma-optical emission spectrometer (ICAP6300, USA). To ensure the accuracy of the detection and analysis, we set up 2 parallel samples for analyses, with the parallel analysis error less than 5%. The analysis results met the quality control requirements, and the mean value of parallel analyses was taken as the experimental results.

Evaluation methods

Geoaccumulation index

Geoaccumulation index (Igeo) is a quantitative index proposed by Muller (Muller, 1969), a sedimentologist at University of Heidelberg Germany in 1969 for researching heavy metal pollution in water environment sediments. This evaluation method considers not only anthropogenic pollution factors and the environmental geochemical background value, but also takes into account the background value caused by natural diagenesis, grading heavy metal pollution intuitively. The calculation formula is as follows:

$$I_{geo} = \log_2 \left( \frac{C_n}{K \cdot B_n} \right)$$

where $C_n$ represents the measured content of element n in sediments, $K$ is a parameter selected considering that rock difference may lead to a change in the background value, generally set to 1.5, $B_n$ represents the geochemical background value of this element, and in this study, the average environmental background value of elements in Dongting Lake sediments is used as the reference value (Table 1). The degrees of pollution can be divided into 7 levels according to the value of $I_{geo}$ (Förstner et al., 1990) (Table 2).
The Potential Ecological Risk Index (RI) is an evaluation proposed by Hakanson (Hakanson 1980), which considered the comprehensive consideration of the toxicity of heavy metals, the sensitivity of the evaluation area to heavy metal pollution, and the difference in background values of heavy metals. It can comprehensively reveal the potential ecological impact of heavy metals in sediments. The calculation formula is as follows:

$$\text{RI} = \sum_{i=1}^{n} E_i^r = \sum_{i=1}^{n} T_r^i \times \frac{C_i}{C_{i^r}}$$

where RI represents the comprehensive multiple-factor of potential ecological risk index, $E_i^r$ represents the single-factor hazard index, and $T_r^i$ represents the toxic response factor, reflecting the toxicity level of heavy metals and the sensitivity of organisms to heavy metal pollution. The $T_r^i$ value of Hg, Cd, As, Pb, Cu and Cr is 40, 30, 10, 5, 5 and 2 respectively. $C_i$ represents the measured value of heavy metal concentration, and $C_{i^r}$ represents the reference value of heavy metals. In this paper, the mean environmental background value of the sediment elements in the Dongting Lake water system is used as the reference value. The background value of heavy metals in the sediments of Dongting Lake is shown in Table 1.

### Table 1. The environmental background value of heavy metals in sediments.

| items | Cu (μg/kg) | Zn (μg/kg) | Cd (μg/kg) | Hg (μg/kg) | Pb (μg/kg) | As (μg/kg) | Cr (μg/kg) | Ni (μg/kg) |
|-------|------------|------------|------------|------------|------------|------------|------------|------------|
| Value | 20.3       | 83.3       | 0.33       | 0.047      | 23.3       | 12.9       | 44.0       | 21.2       |

### Table 2. Geoaccumulation index ($I_{geo}$) sediment quality and Biototoxicity grading standard.

| $I_{geo}$ | Sediment quality                | mPEC-Q                                      | PTP              |
|-----------|--------------------------------|---------------------------------------------|------------------|
| $I_{geo} \leq 0$ | Unpolluted                          | $m\text{PEC} - Q \leq 0.1$                | $\text{PTP} \leq 14\%$ |
| $0 < I_{geo} \leq 1$ | Unpollotted to moderately polluted                          | $0.1 < m\text{PEC} - Q \leq 1$                | $15 < \text{PTP} \leq 29\%$ |
| $1 < I_{geo} \leq 2$ | Moderately polluted                                  | $1 < m\text{PEC} - Q \leq 5$                | $33 < \text{PTP} \leq 58\%$ |
| $2 < I_{geo} \leq 3$ | Moderately to highly polluted                      | $5 < m\text{PEC} - Q$                  | $75 < \text{PTP} \leq 81\%$ |
| $3 < I_{geo} \leq 4$ | Highly polluted                                    |                                             |                  |
| $4 < I_{geo} \leq 5$ | Highly to very highly polluted                         |                                             |                  |
| $I_{geo} > 5$ | Very highly polluted                          |                                             |                  |

### Potential ecological risk index

The Potential Ecological Risk Index (RI) is an evaluation proposed by Hakanson (Hakanson 1980), which considered the comprehensive consideration of the toxicity of heavy metals, the sensitivity of the evaluation area to heavy metal pollution, and the difference in background values of heavy metals. It can comprehensively reveal the potential ecological impact of heavy metals in sediments. The calculation formula is as follows:
system is taken as the reference value. RI, $E_i^j$ and potential ecological risk levels are shown in Table 3.

**Toxicity adverse impact assessment**

mPEC-Q is a biological effect-based method proposed by Ingersoll (Ingersoll, 2001) to evaluate heavy metals in sediments. Its calculation formula is as follows:

$$\text{mPEC} = \sum_{i=1}^{n} \frac{(C_i / PEC_i)}{n}$$

where $C_i$ represents the measured concentration of heavy metal $i$ in sediments, $PEC_i$ represents the possible effective concentration of heavy metal $i$, and $n$ represents the types of heavy metals. In order to further evaluate the potential ecological hazards of heavy metals in sediments, the likelihood of the occurrence of biotoxicity can be judged by comparing the content of a single heavy metal with the corresponding threshold effect concentration (TEC) and possible effective concentration (PEC). Lower than TEC means that ecotoxicity will not occur, while higher than PEC means that ecotoxicity will occur frequently. According to the calculation results by MacDonald (MacDonald et al., 2000), the TEC (PEC) of heavy metals Hg, As, Cr, Cd, Pb and Cu is 0.18 (1.06), 9.79 (33.0), 43.4 (111), 0.99 (4.98), 35.8 (128) and 31.6 (149) respectively. The biotoxicity is divided into 4 levels according to the calculation results, as shown in Table 2 (PTP represents the likelihood of the occurrence of biotoxicity).

**Results and discussion**

**The distribution characteristics of heavy metal content**

According to the content of heavy metals in sediments at the sampling points in the Dongting Lake water system (Figure 2), the content of heavy metals in the sediments range from 0.00 mg/kg to 129.02 mg/kg, and the mean mass fraction of heavy metals showing as follows: $\omega$Cr > $\omega$Pb > $\omega$Cu > $\omega$As > $\omega$Cd > $\omega$Hg. At the sampling points of lake area, the content of Cr in order of size is: Datong Lake (C15, 118.4) > East Dongting Lake (C18, 89.9) > South Dongting Lake (C17, 78.3) > West Dongting Lake (C16, 77.2). The content of As: East Dongting Lake (20.3) > West Dongting Lake (10.4) > Datong Lake (10.1) > South Dongting Lake (8.6). The content of Pb: East Dongting Lake (57.6) > Datong Lake (54.3) > South Dongting Lake (38.4) > West Dongting Lake (36.8). The content of Cu: Datong Lake (71.4) > East Dongting Lake (36.7) > West Dongting Lake (33.2) > South Dongting Lake (30.3). The content of Cd: West Dongting Lake (4.78) > Datong Lake (4.21) > South Dongting Lake (2.33) > East Dongting Lake (2.09). The content of Hg: Datong Lake (0.039) > East Dongting Lake (0.279) > South Dongting Lake (0.197) > West Dongting Lake (0.037). Except the As is equal to the background value of heavy metals in the sediments of Dongting Lake (12.9 mg/kg), the mean content of heavy metals in the lake area of Hg, Cr, Cd, Pb and Cu is 7.0, 2.0, 9.3, 2.2 and 2.3 times of the background value respectively. In the inflowing rivers, the contents of As, Pb and Cu in C02 and C11 are the highest, and the content of Cu in C11 is 33.7 times as much as that in C07 and 4.9 times as much as the background value of Dongting Lake. The maximum concentration of Cr appeared in C04, the mass concentration was 116.71 mg/kg, and the second concentration was in C11, the mass concentration was 114.39 mg/kg, which was 2.7 and 2.6 times of the background value, respectively. In the Yangtze River mainstream sampling points, except for As lower than the background value, the other heavy metals contents in C01 and C23 sampling points are higher than the background value, while only Cr and Cd contents in C24 sampling points are higher than the background value.

The distribution of heavy metals in sediments of Dongting Lake water system has an obvious spatio-temporal difference (Figure 3). According to a simultaneous comparison of the monitoring data of heavy metals in sediments measured in 2003–2010 and 2010–2015 (Fenfang, L. I., et al., 2017; Zuo et al., 2013), the content of As and Cd has decreased in stages in recent years. As of the present study, the content of As is the same as the background value, but the content of Cd is still far above the background value, which is 9.3 times of the a background value. The Pb and Hg contents are increasing over time, with the Hg content increasing to 7.0 times of the background value. The Cr and Cu content increased in 2010–2015 after the decrease, but it was still lower than the average in 2003–2010. In 2017, there was no major difference in heavy metal content between the lake region and the inflowing rivers. Expect Cu, the content of the rest 5 heavy metals was slightly higher than that in the inflowing rivers, which was 1.1–1.5 times of the inflowing rivers. The results show that the concentration of heavy metals in sediments of the lake area is obvious, and the contents of different heavy metals in the same...
inflow system vary greatly, and the contents of the same heavy metals in different inflow systems differ significantly, indicating that the contribution of the inflow system to the heavy metals in the sediments of Dongting Lake is different.

**Assessment by geo-accumulation index method**

Figure 4 shows the heavy metal pollution grade distribution ($I_{geo}$) at various sampling points. The $I_{geo}$ range of Hg, As, Cr, Cd, Pb and Cu in sediments is $-1.12 \sim 4.24$. 
−2.31 ~ 0.65, −2.06 ~ 0.84, −0.42 ~ 3.78, −1.11 ~ 1.88 and −3.35 ~ 1.72 respectively, and all the heavy metals are pollutants: Cd is moderately to highly polluted and Hg is moderately polluted. Among the inflowing rivers, Cd is unpolluted in the Zijiang River (C07) and unpolluted to moderately polluted in Yuanshui River (C08), while in the rest eight lake inlets, Cd is something between moderately polluted and highly polluted. In the lake region, Cd is only unpolluted to moderately polluted in C13, while it is a something between moderately to highly polluted and highly polluted at the rest points. Cd is something between moderately polluted and highly polluted at C01, C23 and C24. The degree of Hg pollution in the lake region is higher than the inflowing rivers, and Hg is highly to very highly polluted at C02 and C22.

Potential ecological risk assessment and biotoxicity adverse impact assessment

According to the potential ecological risk grade of a single heavy metal (Figure 5), Cd and Hg are at the high risk, while the rest heavy metals are at the low risk, suggesting that Cd and Hg are major
contribution factors to the ecological risk. This result is consistent with the current study result (Xie et al., 2017; Zhang et al., 2015). The risk degree of Cd and Hg in the lake region is generally higher than that in the inflowing rivers. The present situation of Cd pollution in Dongting Lake is very serious, where it is at the high and very high ecological risk except C13. In the inflowing rivers, Cd is at the high and very high ecological risk at all the points except C07 and C08; Cd is at the considerable risk, very high risk and high ecological risk at C01, C23 and C24 respectively.

According to the comprehensive potential ecological risk grade of heavy metals (Figure 6), the RI value at the sampling points in the Dongting Lake water system ranges from 47.0 to 1642.4. There is an obvious difference in ecological risk level among the inflowing rivers, the ecological risk level is relatively centralized in the lake region, and the RI value of heavy metals from high to low is Cd > Hg > Cu > Pb > As > Cr. Among the inflowing rivers, C02 and C03 are at the very high risk level, C05, C06, C09 and C11 are at the high risk level, while C07 is at the low risk level. Among the sampling points in the lake region, all points are at the high and very high risk level except C12 and C13. Among them, the East, South, West Dongting Lake and Datong Lake are at the high risk level.

The ratio of heavy metal content to the corresponding TEC shows that the concentration of all the 6 heavy metals are higher than TEC, and the ratio of Cd concentration to TEC is highest, suggesting that benthic organisms in sediments were more likely to be harmed by Cd. The degree of heavy metal pollution from high to low is Cd > Cr > Cu > Hg > Pb > As. As shown in Figure 6, the mPEC-Q value of heavy metals in sediments at various sampling points is between 0.11 and 0.93, with the mean value being at 0.43, it shows 15%~29% chance of serious biotoxicity in the study region. The maximum mPEC-Q value appears at C22, indicating that the biotoxicity of heavy metals in sediments at this point produces the most adverse effect. The minimum appears at C07, indicating that biotoxicity has the least adverse effect, and that the changing trend of the mPEC-Q value is basically the same as that of the RI value.
In this research, we evaluated the study region using three evaluation methods, the results showing that Cd was moderately to highly polluted, at the high risk level, and might cause harm to benthos organisms, which is the heaviest polluted heavy metal. Hg was moderately polluted, at the high risk level, but it might contribute little to the production of biotoxicity in the study region, with its pollution level next only to that of Cd. These evaluation methods showed a certain difference in results, suggesting that a single method has its limitations. Therefore, different results achieved by multiple evaluation means can be used as a more comprehensive and scientific theoretical reference to the prevention and control of heavy metal pollution in the Dongting Lake water system.

**Analysis of the possible sources of heavy metals in sediments**

SPSS 20.0 was used to make a cluster analysis of the content of the six heavy metals at twenty-one sampling points (C02-C22) in the study region, and then variable clustering was performed on standardized data [0–1] by inter-group linkage method and squared Euclidean distance method. See Figure 7 for the results, As, Pb, Cd and Cu are under the first category, Hg is under the second, and Cr is under the third. It can be qualitatively recognized that the spatial variation law of As, Pb, Cd, Cu and other heavy metals content is relatively consistent, and that the content of the heavy metals under the first category is distributed relatively uniform, suggesting that As, Pb and Cu come from the same source as Cd. Hunan Province abounds in mineral resources. By the end of 2015, 143 kinds (sub-kinds) of minerals had been discovered, including 101 of proved reserves. Since the beginning of the reform and opening-up policy, Hunan Province has achieved rapid mining development and gradually formed distinctive industrial systems supported by mineral exploitation and processing, including an iron and steel industrial system with Lianyuan steel and Hunan steel as the core players, a lead and zinc industrial system with the lead and zinc mines in Huangshaping and Shuikou Mountain and the Zhuzhou Metallurgical Plant as the core player. Although the comprehensive governance has been conducted over industrial and mining enterprises on a large scale, and universally making the content of heavy metals in sediments in the inflowing rivers lower than the lake region, the content of all the heavy metals except As is higher than the background value, suggesting that there are currently still anthropogenic heavy metal pollution sources. On the other hand, due to wide population distribution in the cities and towns around the Dongting Lake, the lake receives lots of domestic sewage and irrigation wastewater, As, Pb, Cd and Cu come mainly from industrial effluents and domestic sewage (Zhang, 2015). Hg is under the second pollutant category. Hunan Province abounds in precious metal and mercury ore resources and research shows that Hg comes mainly from non-ferrous metal mining (Wan et al., 2011). In this study, there is the highest degree of pollution at C02 and C22, which are heavy pollution. C22 is an outlet of the Dongting Lake and the pollution may be attributed to long-term specific hydrologic conditions and sediment velocity. The Dongting Lake region is a “fertile land of fish and rice” of Hunan and even the whole country, and crops are planted highly densely in this region. C02 is located at an inlet of the Ouchi River and the content of Hg at this sampling point is very high, this might be attributed to excessive chemical fertilization, such as the excessive application of phosphate fertilizers. The third category of pollution source is Cr, which has an even distribution as a mild pollutant, especially in the lake region. The Dongting Lake
region is a major schistosoma endemic area in China, in order to exterminate oncomelania hupensis, the schistosoma’s intermediate host, a large amount of chemical agents, such as chromium slag, were applied to the lake, suggesting that the chemical agents might be one of the sources of Cr.

A principal component analysis was made on the heavy metals in sediments in the Dongting Lake water system (C02~ C22) (KMO test: 0.604, Bartlett’s test of sphericity: 0.000). As can be seen in Figure 8, all the information represented by the 6 heavy metals in sediments can be reflected with the first 2 principal components ($\lambda_1 = 2.544, \lambda_2 = 1.960$), respectively explaining 42.4% and 32.7% of the total pollution. Hg, Pb, As and Cd account for a high proportion of the first principal component, suggesting that the four heavy metals are the main pollutants in the sediments, and that there is a strong correlation among them. Cr and Cu account for a high proportion of the second principal component, suggesting that there is a significant correlation between the two heavy metals and Pearson correlation analysis results corroborate with the present results. Through the analysis of the score of each principal component (Figure 9), analyses of the various principal components show that C02, C04 and C12 are scored better in the first principal component (F1), suggesting that the three areas are mainly polluted by Hg, Pb, As and Cd. C03, C15 and C19 are scored better in the second principal component, suggesting that the three areas are mainly polluted by Cr and Cu. As for the score F1 in the first principal component, the score of C22 is significantly higher than that of the rest point locations, suggesting that there is high content of Hg, Pb, As and Cd at C22, and that the heavy metal composition has high complexity. As for the score F2 in the second principal component, the score of C11 and C22 is obviously higher than that of the rest point locations, suggesting that there is high content of Cr and Cu at C11 and C22. According to comprehensive scoring, C22 has the highest score, suggesting that this sampling site is featured by the highest comprehensive heavy metal content and composition complexity.

Conclusions
To accurately “diagnose” the Dongting Lake water system, this paper evaluated the content of six heavy metals in twenty-four sampling points in the surface sediments of Dongting Lake water system during normal water period and analyzed their risk assessment by using the methods of index geoaccumulation, potential ecological risk assessment and toxicity adverse impact assessment. The results show that the Dongting Lake water system has been seriously polluted. The average value of As is equal to the environmental background value of heavy metals in sediments in the Dongting Lake, and the rest contents of Hg, Cr, Cd, Pb and Cu are 7.0, 2.0, 9.3, 2.2 and 2.3 times of background value in the lake area, respectively. Except for Cu, the average content of the other five heavy metals in the lake area is slightly higher than that of the lake system, which is 1.1–1.5 times of the heavy metal content in the sediments of the lake system. In this study, the concentration of the heavy metals in sediments at the lake entrance is relatively low, but the inflowing water systems are still the main sources of heavy metal pollution in the lake region. In the next phase of the study, the scope should be expanded and the sampling density should be increased, the pollution status in the dry season should be considered also. Besides, the main types of pollution and river sections of each lake system will be further clarified. In addition, all of the studied heavy metals in sediments are under a state of contamination, Cd is moderately to highly polluted and Hg is moderately polluted, the RI value at the sampling points ranges between 47.0 and 1642.4, and the order of heavy metal RI values from large to small is Cd > Hg > Cu > Pb > As > Cr, the average mPEC-Q value of heavy metals is 0.43, showing that the possibility of adverse effects of biotoxicity is between 15% and 29%, it indicates the Dongting Lake has been seriously polluted. According to source analyses, the main polluting heavy metals in the Dongting Lake are Cd and Hg, while As, Pb, Cd and Cu are homologous and mainly come from industrial wastewater. Therefore, the treatment of Dongting Lake water system should focus on the sources of heavy metals such as As, Pb, Cd, and Cu, and supervision should be constantly strengthened. Particularly, it is imperative to further promote the transformation and upgrading of the polluting enterprises along the “Four Rivers” basins to strictly control the discharge systems. Meanwhile, the practical application research of biological snail control should be strengthened in all regions and try to be the first in implementing “The
Ecological Snails Control”.

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