Pollution characteristics and risk assessment of heavy metals in sediments of Wolong Lake

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Abstract: In this paper, the heavy metal content in the surface sediment of 20 sampling points in Wolong Lake of Shenyang was analyzed. The accumulation degree and potential risk of heavy metal pollution in the sediment were evaluated by the geological accumulation index and potential ecological risk index. The results showed that the order of the six heavy metals accumulation index was Cd > Zn > Ni > Cr > Cu > Pb. According to the relevant evaluation standards, the main heavy metal pollutant in the sediment was Cd, and the risk order of ecological hazards was Cd > Ni > Cu > Zn = Pb > Cr. The evaluation of potential ecological risk index showed that the risk level of heavy metals in the sediment of Wolong Lake was low.

1. Introduction

Heavy metals were widely distributed in nature, with strong enrichment and difficult to degrade. Heavy metals were present into the river through the discharge of industrial and agricultural sewage, surface runoff, atmospheric sedimentation and other ways, and then through adsorption, complexation, flocculation, sedimentation and other effects deposited in lakes and other sediments. When the surface of the lake sediment were affected by the external environment, the heavy metals in the sediment will be released to the water ecological environment, absorbed by aquatic organisms, enriched in the body or even to the extent of toxicity, and transmitted through the food chain to threaten higher organisms, including human beings. Therefore, heavy metal pollution in lake sediment had been paid more and more attention³,⁴.

Wolong Lake was the largest inland wetland in Liaoning Province. It was a provincial nature reserve based on waterfowl habitat protection and aquatic resources. The total drainage area was 1592 square kilometers, the water surface area was 60 square kilometers, the maximum storage capacity was nearly 100 million cubic meters, the average depth was 1.5-2 meters, and the average annual temperature was 6.9°C. It was a typical plain freshwater lake wetland in the north of China, which belonged to the first class ecological sensitive zone in China. Heavy metal pollutants from domestic pollution sources, agricultural irrigation pollution sources and industrial pollution sources will flow into Wolong Lake through runoff, so it was very important to study the pollution characteristics and degree of Wolong Lake Sediment for environmental protection and management³,⁴.

In this paper, the potential ecological risk index method was used to analyze the heavy metal content in the surface sediment of Wolong Lake in 2019 to study the pollution characteristics of heavy
metal in the sediment of Wolong Lake, and to evaluate the potential ecological harm of heavy metals in the sediment of Wolong Lake, in order to master the pollution dynamics of the surface sediment of Wolong Lake. Through this study, we could provide the basis for environmental management, ecological risk prevention and control of Wolong Lake.

2. Materials and methods

2.1. Sample collection and processing
Surface sediments of Wolong Lake were collected by sediment sampler in August 20, 2019 (The settings of sampling points were shown in Figure 1). Transferred the collected surface sediment sample to a clean enamel plate, after natural air drying, grinded through 100 mesh nylon screen, used quartering method to get the analysis sample, and put it into polyethylene plastic bag for storage[5,6].

2.2. Analytical methods
Zn, Pb, Cu, Cd were determined by plasma mass spectrometry, Cr by X-ray fluorescence and Ni by plasma emission spectrometry. Through the parallel sample test, the results of relative deviation of each analysis item met the quality control requirements, and the relative error of recovery rate of all tested elements was within the allowable error, which proved that each measurement item was accurate and reliable. In addition to boric acid, all the reagents used in the experiment were of superior purity, and the water for solution preparation was ultrapure water[6,7].

2.3. Geological accumulation index method.
Professor Muller of the Institute of Sediment Research of Heidelberg University in Germany proposed the method of geological accumulation index ($I_{geo}$) to quantitatively evaluate the pollution degree of heavy metals in aquatic sediment in 1969. From the perspective of environmental geochemistry, the geological accumulation index method taken into account not only human pollution factors and environmental geochemical background values, but also the factors (constants) that may cause background value changed due to natural diagenesis[8,9]. The relationship between geological accumulation index and heavy metal pollution degree was shown in Table 1.

The calculation formula of $I_{geo}$ is as follows:

$$I_{geo} = \log_2 \frac{c_n}{1.5\beta_n}$$

$c_n$ was measured mass fraction of heavy metals; 
$\beta_n$ was background value of heavy metals in local sediments; 
1.5 was a constant set considering that diagenesis may cause background value fluctuation.
Table 1. The relationship between geological accumulation index and heavy metal pollution degree

| Degree | Igeo | Degree of contamination |
|--------|------|-------------------------|
| 0      | ≤0   | clean                   |
| 1      | 0 < Igeo ≤1 | mild pollution          |
| 2      | 1 < Igeo ≤2 | moderate pollution        |
| 3      | 2 < Igeo ≤3 | medium pollution           |
| 4      | 3 < Igeo ≤4 | tend to heavy pollution    |
| 5      | 4 < Igeo ≤5 | heavy pollution             |
| 6      | >5   | severe pollution          |

The background values of Cd, Cr, Cu, Ni, Pb and Zn were 0.16, 57.7, 24.6, 27.9, 22.2 and 59.8 mg/kg, respectively.

2.4. Potential ecological risk index method

Swedish scholar Hakanson\[10\] established a set of methods to evaluate heavy metal pollution and ecological harm of aquatic sediment based on sedimentology principle in 1980, namely potential ecological harm index method. In this method, the effects of environmental chemistry, biotoxicity, ecology and other aspects were comprehensively considered. The toxic response coefficient was used to reflect the toxic effects of various heavy metals, the toxicity of heavy metals and the possible environmental ecological hazards were considered. The degree of potential hazards of heavy metals was divided by quantitative method, and the evaluation results provided basis for environmental improvement. At present, this method had been widely used in sediment ecological risk assessment, and had become one of the international methods of soil (sediment) heavy metal assessment.

\[ C_i = \frac{C_{i,\text{surface}}}{C_{i,\text{b}}}; \]
\[ E_i = T_{i} \cdot C_i; \]
\[ RI = \sum_{i=1}^{n} E_i \cdot \frac{1}{T_{i} \cdot C_i}. \]

Among them, the toxicity response coefficients of Cd, Cr, Cu, Ni, Pb and Zn were 30, 2, 5, 5, 5 and 1; \( E_i \) was potential ecological risk index of heavy metal i; RI was combined potential ecological risk index of heavy metals in sediment\[11\]. Classification of potential ecological risk index was shown in Table 2.

Table 2. Classification of potential ecological risk index

| Single-factor pollutant pollution index \( C_i \) | Potential ecological risk parameters \( E_i \) | Potential ecological risk index RI |
|-------------------------------------------------|-----------------------------------------------|----------------------------------|
| Classification Grade | Classification Grade | Classification Grade |
| low | low | low |
| medium | medium | medium |
| heavy | heavy | heavy |
| severe | severe | severe |

\( C_i \geq 6 \)
3. Results

The geological accumulation index and potential risk index of heavy metals in the sediments of Wolong Lake were shown in Table 3. The order of six heavy metals accumulation index in the sediments of Wolong Lake was Cd>Zn>Ni>Cr>Cu>Pb, The mean value of $I_{geo}$ was -0.42. The overall pollution level was clean. The pollution degree of six heavy metals in the sediment was: Cd accumulation index was 1.51, which was moderate pollution; Zn and Ni accumulation index were 0.62 and 0.46, which were light pollution; Cr, Pb and Cu accumulation index were -0.43, -1.71 and -1.12, which were clean, respectively. Cd was the main pollution of the six heavy metals in the sediments of Wolong Lake. In the evaluation of single factor pollution degree, the single factor pollution degree of heavy metals in sediment was Cd> Zn > Ni > Cr> Cu >Pb, and Cd pollution was serious. The potential ecological risk assessment method showed that the average ecological risk level of Cr, Cu, Ni, Pb, Zn in the sediment of 20 sampling points was low, and the potential ecological risk level of Cd in the sediment was heavy. The comprehensive ecological risk level of heavy metals in the sediments of Wolong Lake was low.

| Elements | Igeo | Grade | $C^f$ | $E^r$ | Grade | RI | Grade |
|----------|------|-------|-------|-------|-------|-----|-------|
| Cd       | 1.51 | medium| 4.27  | severe| 128.2 | heavy| 148.8 | low   |
| Cr       | -0.43| clean | 1.11  | medium| 2.2   | low  |       |
| Cu       | -1.12| clean | 0.69  | low   | 3.5   | low  |       |
| Ni       | 0.46 | mild  | 2.06  | medium| 10.3  | low  |       |
| Pb       | -1.71| clean | 0.46  | low   | 2.3   | low  |       |
| Zn       | 0.62 | mild  | 2.31  | medium| 2.3   | low  |       |

4. Discussion and conclusion

The study on Cd in Yelang Lake sediment showed that the evaluation results of land accumulation index method and potential ecological hazard index method were basically the same. For Cd in sediment in low water period. The pollution degree was relatively large, from no pollution to tertiary pollution or light pollution to extremely strong pollution, the pollution degree in the middle reaches was relatively light, followed by the upstream, and the downstream was the most serious, while the pollution degree in the dry season was significantly higher than that in the dry season[12]. The evaluation results of geological accumulation index method and potential ecological risk evaluation index method were basically the same in this study. Among the six heavy metals in Wolong Lake sediment, Cd was the primary pollution, the potential ecological risk level of Cd was relatively high, and the comprehensive ecological risk level of heavy metals in Wolong Lake sediment was low.

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