Heavy Metals Pollution Characteristics and Ecological Risk Assessment of the Sediments of Anrongjing River in Taizhou City

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Abstract. In order to study the heavy metals pollution in the river channel of the city, this paper based on the results of the sediments detections of Anrongjing River in Taizhou, using the single pollution index method, the potential ecological risk index method, the cluster analysis method and other methods to evaluate the content, the degree of pollution, the distribution, ecological risk assessment, etc. of heavy metals. The results show that Cu, Zn, Pb and Cd in the sediments are seriously polluted. Viewed from the plane, the main pollution areas are the upstream, the two tributaries and the tributaries and main river crossings. Viewed from the vertical, the heavy metals pollution roughly decreases with increasing sediments depth. The results of heavy metals ecological risk assessment show that the potential ecological hazards of Cu and Cd are serious, the pollution of Cd and Cu in the source, the two tributaries and tributaries and main river crossings are the most serious.

1. Introduction
In recent years, the heavy metals contents in the sediments of many urban rivers greatly exceed the local soil environmental background value [1]. Heavy metals have bio-chain enrichment effects, which not only damage the ecological environment of rivers, but also endanger aquatic life and human health. River sediments is an important "source" and "sink" of pollutants in the water environment [2]. The heavy metals in the sediments mainly come from the domestic sewage and industrial wastewater, followed by the soil erosion around the river and lake, and then the weathering of the rock. The heavy metals contents in the sediments and its characteristics are important indicators for evaluating the pollution status of the water environment [3]. Based on the results of sediments detection in Anrongjing River, this paper analyzes the characteristics of heavy metals pollution in river sediments and evaluates the potential ecological risk of heavy metals in sediments in the study area. It provides scientific method to prevent and renovate the heavy metals pollution in urban river sediments.

2. Research area
The river is located in the vicinity of Anrong Village and Luxi Village, Fengjiang Street, Luqiao District, Taizhou City. It starts from Anrong Village and converges in Nanguan River at Anguan Temple. It is about 3 kilometers long (including 2 tributaries). The width of the river is 10-38 meters, the depth of the river is about 2.1-3.2 meters, and the area is about 0.061 square kilometers. There is one tributary in each side, and the source of the south tributary is a pond. The upper elevation of the
main channel and the north tributary are higher than the middle and lower reaches. The water and sediments are polluted on different degrees by the original dismantling industry, agricultural pollution and domestic sewage.

3. Samples and evaluation method

3.1. Samples
According to the comprehensive factors such as the water area, the section characteristics, the flow velocity and the representativeness and uniformity of the samples of the sediments, we select sampling points at typical sections and based on grid method. The principle is the "Monitoring emphatically at the most polluted reach". All we did is to ensure that the collected samples can fully reflect the overall condition of the river sediments. Therefore, 11 sampling points are selected, and 22 samples are collected. The sampling points are arranged as shown in Figure 1.

Figure 1. Bitmap of sample points of Anrongjing River

3.2. Evaluate method

3.2.1. Single pollution index method. According to the Control Standards for Soil Environmental Risks of Agricultural Lands (GB 15618-2018) and Control Standards for Pollutants in Agricultural Sludge (GB4284-2018), the single-item pollution index method is used to evaluate the heavy metals in sediments.

3.2.2. Potential ecological risk index method. The author use potential ecological risk index method to evaluate the heavy metals in sediments, which was proposed by Swedish scholar Hakanson in 1980. It comprehensively considers the toxicity, ecological and environmental effects of heavy metals in sediments, and has been widely used in the evaluation of heavy metal pollution in sediments [4-9]. The formula for calculating the potential ecological risk index RI is:

$$RI = \sum E_i^l = \sum T_i^l \cdot C_i^l = \sum T_i^l \cdot \left(C_i^l / C_i^b\right)$$

In the formula, $C_i^l$ is pollution coefficient of heavy metals relative to background values($C_i^l = C_i^b / C_i^b$); $C_i^l$ is the environmental measured value of heavy metal $i$; $C_i^b$ is the background value of heavy metal $i$, which is Cd(30) > Pb(5) = Cu(5) > Ni(2) > Zn(1); $E_i^l$ is the potential ecological risk coefficient of heavy metal $i$; RI is a potential ecological risk index and is a combination of several potential ecological risk coefficients of heavy metal.

It is divided into five grades from low to high when describes the pollution degree of a certain pollutant using the potential ecological risk coefficient; A potential ecological risk index is the
addition of multiple potential ecological risks at a certain point, which is divided into four grades. Both the grading standards are shown in Table 1.

**Table 1. Grading standards of potential ecological risk coefficient and potential ecological risk index**

| potential ecological risk coefficient $E_i$ | potential ecological risk index $RI$ | potential ecological risk level |
|--------------------------------------------|-------------------------------------|--------------------------------|
| Less than 40                                | Less than 150                       | slight                         |
| From 40 to 80                               | From 150 to 300                     | moderate                       |
| From 80 to 160                              | From 300 to 600                     | intensity                      |
| From 160 to 320                             | No less than 600                    | strong                         |
| No less than 320                            |                                     | extremely strong               |

### 4. Results and discussion

#### 4.1. Distribution characteristics of heavy metals contents in sediments

**4.1.1. Horizontal distribution characteristics of heavy metals in sediments.** As the test results, the contents of Cu, Zn, Pb, Cd in survey area were higher than the risk screening values. Over-standard positions of Cu are 2#, 3#, 4#, 5#, 7#, 8#, over-standard positions of Zn are 1#, 2#, 3#, 4#, 5#, 7#, over-standard positions of Pb are 2#, 3#, 5#, 7#, over-standard positions of Cd are 1#, 2#, 3#, 5#, 6#, 7#, 8#, 9#, 10#, 11#, over-standard position of Ni is 4#, over-standard positions of Cr are 1# and 4#, over-standard position of Hg is 2#. As did not exceed the standard. It can be seen from the positions of the over-standard samples that the contaminated areas of heavy metals are the upstream section, the two tributary sections and the crossings of tributaries and main river (as shown in Figure 2).

![Figure 2. Over-standard area of heavy metals](image)

**4.1.2. Vertical distribution characteristics of heavy metals in sediments.** According to the test results, the sampling points of Cu over-standard are 3#, 4#, 5#, 7#, 8#, and the sampling points of Zn over-standard are 1#, 3#, 4#, 5#, 7#, 8#, sampling points of Zn over-standard are 5#, 7#, and the sampling points of Cd over-standard are 1#, 2#, 5#, 7#, 8#, 9#. As shown in Figure 3, the ordinate in the figure is the ratio of the heavy metal content at each point to the corresponding heavy metal risk screening value in GB15618-2018. The Cu contents of the sludge layer and the clay layer at the sampling points of 3#, 4#, 7#, and 8# exceeded the standard, but the Cu contents of the clay layer were significantly reduced compared with the sludge layer; the Zn contents of the sludge layer and the clay layer both exceeded the standard, but the Zn contents of the clay layer were significantly lower than that of the
sludge layer, which decreased from 1320 mg/kg to 525 mg/kg; the Pb contents of the sludge layer of 2# and 3# samples exceeded the standard, but the Pb contents of the clay layer were within the standard range. The Cd contents of clay layer at 2#, 3#, 5#, 6#, 7#, 8#, 10#, 11# also have a certain degree of decline compared with the surface sludge layer.

The heavy metals contents of clay layer in individual points are higher than that of the sludge layer, which may be related to the historical pollution or the water washing accelerates the release of heavy metals, but in general, as the depth of the layer increases, the concentration of heavy metals generally decreases.

![Graph](image)

(The ratio is the result of the heavy metal content at each point divided by the corresponding heavy metal risk screening value)

**Figure 3. Vertical comparison of heavy metals in sediments**

4.2. Cluster analysis of heavy metals in river sediments

The sources of heavy metals in river sediments are controlled by various factors, such as rock materials, industrial and agricultural activities [10], and there is a correlation between heavy metals of the same source. The correlation between heavy metal content and soil properties in soil is not only affected by the nature of the element itself but also related to the environment and source of the element [11]. The cluster analysis method to analyze the correlation of heavy metal elements and their sources has been widely used [12, 13]. The cluster analysis of eight heavy metals in this project was carried out, and the results were represented by a systematic tree diagram (as shown in Figure, 4). According to the analysis results, heavy metals can be divided into two categories: Zn; Cd, As, Hg, Ni, Pb, Cr, Cu. Zn is different from other heavy metals, while the other seven heavy metals are affected by the same factor.
4.3. Potential ecological risk of heavy metals in sediments

According to the formula of potential ecological risk coefficient of heavy metal $E_i^l$ and potential ecological risk index RI proposed by Hakanson, the author calculated the potential ecological risk index of heavy metals in sediments samples from Anrongjing River basing on the test results, which is shown in Table 2.

Table 2. Evaluation table for potential ecological risk of heavy metals in sediments

| NO. | Location | Cu  | Zn  | Pb  | Cd  | Ni  | RI |
|-----|----------|-----|-----|-----|-----|-----|----|
| 1#  | 0cm      | 7.16| 3.68| 3.50| 34.5| 5.45| 54.3|
|     | 40cm     | 7.25| 4.39| 15.3| 446.9| 5.48| 479 |
| 2#  | 0cm      | 153 | 37.4| 25.8| 734.9| 1.07| 952 |
|     | 40cm     | 5.03| 1.58| 2.77| 67.8 | 2.93| 80.1|
| 3#  | 0cm      | 119 | 11.9| 23.6| 105  | 6.05| 265 |
|     | 40cm     | 26.5| 4.75| 7.25| 11.2 | 4.77| 54.5|
| 4#  | 0cm      | 23.9| 4.69| 9.05| 8.22 | 3.53| 49.4|
|     | 40cm     | 12.7| 11.3| 7.66| 6.72 | 14.0| 52.4|
| 5#  | 0cm      | 5.61| 8.93| 2.32| 111.7| 4.57| 133 |
|     | 40cm     | 27.9| 4.28| 13.1| 18.2 | 2.91| 66.4|
| 6#  | 0cm      | 5.47| 1.16| 4.10| 126.7| 4.71| 142 |
|     | 40cm     | 5.85| 1.25| 2.69| 12.1 | 5.15| 27.0|
| 7#  | 0cm      | 261 | 2.86| 31.2| 302.6| 1.59| 600 |
|     | 40cm     | 166 | 1.41| 18.1| 220.3| 2.13| 408 |
| 8#  | 0cm      | 31.4| 1.60| 7.94| 61.6 | 3.10| 106 |
|     | 40cm     | 16.4| 1.96| 5.56| 28.5 | 3.15| 55.6|
| 9#  | 0cm      | 5.19| 0.78| 3.04| 6.31 | 5.19| 20.5|
|     | 60cm     | 4.65| 0.73| 1.26| 21.9 | 5.65| 34.2|
| 10# | 0cm      | 5.73| 0.87| 3.84| 146.4| 6.04| 163 |
|     | 40cm     | 16.5| 1.23| 7.59| 8.53 | 5.90| 39.8|
| 11# | 0cm      | 5.63| 0.84| 4.27| 69.8 | 4.21| 84.8|
|     | 40cm     | 6.48| 0.98| 5.79| 6.72 | 5.23| 25.2|

The value of single heavy metal ecological risk index indicates that except for Cu and Cd, other heavy metals have only mild ecological risk and have no potential ecological risk to the river. The ecological risk index of Cu at 2#, 3# and 7# and the ecological risk index of Cd at the 2#, 3#, 5#, 6#, 9#
7#, 8#, 10#, and 11# points belong to intensity and strong, even extremely strong. So it has serious potential risk to river ecology and water quality. The pollution of Cd and Cu in the sediments of the source and the two tributaries and main river crossings are more serious, especially the Cd pollution at the 1# and 2# points is extremely strong (Table 1). So we need special attention to its ecological risk.

5. Conclusion

(1) The contents of Cu, Zn, Pb, Cd in survey area were higher than the risk screening values.

(2) Viewed from the plane, the main pollution areas are the upstream, the two tributaries and the tributaries and main river crossings. Viewed from the vertical, the heavy metals pollution roughly decreases with increasing sediments depth.

(3) Except for Cu and Cd, other heavy metals have only mild ecological risk and have no potential ecological risk to the river. The ecological risk index of Cu at 2#, 3# and 7# and the ecological risk index of Cd at the 2#, 3#, 5#, 6#, 7#, 8#, 10#, and 11# points belong to intensity and strong, even extremely strong. So it has serious potential risk to river ecology and water quality. The pollution of Cd and Cu in the sediments of the source and the two tributaries and main river crossings are more serious, especially the Cd pollution at the 1# and 2# points is extremely strong. So we need special attention to its ecological risk.

References

[1] Zhang X, Zhou T F, Yang X F, Yin H Q and Xiao Z H 2005 Study on assessment methods of heavy metal pollution in river sediments Journal of Hefei University of Technology GY chapter 28 pp1419-23
[2] Jia Y, Fang M, Wu Y J, Liu H, Miu Z, Wang X T, Lin W X, Tong X 2013 Pollution characteristics and potential ecological risk of heavy metals in river sediments of Shanghai China Environmental Science chapter 33 pp147-53
[3] Liu C, Wang Z Y, He Y 2003 Water Pollution in the River Mouths Around Bohai Bay International Journal of Sediment Research chapter 18 pp 326-32
[4] Xu Z Q, Ni J S, Tuo X G 2008 Calculation of Heavy Metal’s Toxicity Coefficient in the Evaluation of Potential Ecological Index Environmental Science &Technology chapter 31pp112-15
[5] Chen J R, Ling Y C, Qian L L, Zhang C, Gao H, Shu Q 2016 Heavy Metal Pollution and Ecological Risk Assessment of Dust from Different Functional Areas of Nanjing City Science Technology and Engineering chapter 16 pp 121-25
[6] Liu B L, Diao G L, Han X, Zhao B, Xue M Y, Cui X T, Niu Q 2015 Spatial Distribution and Ecological Risk Assessment of Heavy Metals in Sediments from Songhua RiverScience Technology and Engineering chapter 15 pp 140-45
[7] Wang X F, Su X Y, Shang F, Chen Y Q 2014 Ecological Risk Assessment of Heavy Metal Element in Soil around Mengershuang Industrial Zone of Xinxian CityScience Technology and Engineering chapter 14 pp 105-09
[8] Cui Y J,Wang H J, Zhao X Q 2012 Evaluation on Pollution Assessment and Ecological Effect of Heavy Metals in the Surface Soil of the Eastern Shandong Province Science Technology and Engineering chapter 12 pp 5841-46.
[9] Lv S C, Zhang H, Shan B Q, Li L Q 2013 Spatial Distribution and Ecological Risk Assessment of Heavy Metals in the Estuaries Surface Sediments from the Haihe River Basin Environmental Science chapter 34 pp 4204-10
[10] Li T J 1995 Soil Environmentology Soil Pollution Prevention and Control, Soil Ecological Protection p91-96
[11] Cheng F, Cheng J P, Sang H C, Yu J L, Xi L, Pi S S 2013 Assessment and Correlation Analysis of Heavy Metals Pollution in Soil of Dajinshan Island Environmental Science chapter 34 pp 1062-66
[12] Liu F, Hu J W, Qin F X, Wu D, Li C X, Huang X F, Jiang C H 2010 An assessment of heavy metal contamination sources in sediments from Hongfeng Lake Acta Scientiae Circumstantiae chapter30pp1871-79
[13] Li Y, Zhou Y Z, Dou L, Du H Y, Lai Q H, Lin X M, Fan R, Du M 2010 Soil heavy sources identification and associated risk assessment using multivariate statistical and Fourier spectral analysis Earth Science Frontiers chapter 17 pp 253-61