

Research Article

Pollution Characteristics and Risk Assessment of Heavy Metal Elements in Sediment in the West Lake of Hengshui Lake

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21 sampling points were set in the West Lake of Hengshui Lake including 20 fish ponds and 1 natural pond to analyze the contents distribution of heavy metal elements including Cr, Zn, Pb, Cu, Cd, Hg, As, and Sb in sediment. The degree of heavy metal pollution was evaluated by the geoaccumulation index (I_{geo}) method. The results showed that the concentrations of Cr, Zn, Pb, Cu, Cd, and Hg at in all sampling points of the fish ponds were lower than soil risk screening values of agricultural land in soil environmental quality: risk control standard for soil contamination of agricultural land (trial) (GB 15618-2018). The concentrations of As at 5 sampling points were higher than soil risk screening values and lower than soil risk control values of agricultural land in GB 15618-2018. The concentrations of Sb were lower than soil risk screening values of construction land in soil environmental quality: risk control standard for soil contamination of development land (trial) (GB 36600-2018). The evaluation results of the geoaccumulation index method showed that the pollution degrees of Cd, Pb, and Hg were moderately contaminated in general, the pollution degree of Cu was uncontaminated to moderately contaminated in general, the pollution degrees of Cr and As were uncontaminated to moderately contaminated in some sampling points, and Zn and Sb could be regarded as uncontaminated in sediment of the fish ponds in the West Lake of Hengshui Lake. Otherwise, the average contents of other heavy metal elements in sediment of the fish ponds in the West Lake of Hengshui Lake were higher than the background value of soil in Hebei Province (BVSH) except for Zn and Sb. The average contents of seven heavy metal elements in sediment of the natural pond in the West Lake of Hengshui Lake were lower than BVSH except for Cr. The result can be regarded as no pollution in the natural pond because the values of I_{geo} were all lower than 0. The heavy metal pollution in the sediment of the West Lake of Hengshui Lake may be due to the introduction of feeding. The water environment of the West Lake of Hengshui Lake can be effectively improved by cleaning up the sediment of fish ponds and “returning fishing to wetland.”

1. Introduction

The heavy metal pollution has the characteristics of strong toxicity, easy accumulation, and nondegradation, which is one of the key points in the current environmental pollution prevention and control work. The sediment in the lake usually has a strong accumulation effect on heavy metal elements because heavy metal elements in lake can be enriched in sediment through a variety of biological and physicochemical processes. The contents of the heavy metal elements in sediment in lake are often much higher than

that in the water itself, which may be hundreds or even tens of thousands of times of its content in the water. The heavy metal elements in sediment may be released into water under the certain conditions. It may lead to the secondary pollution of water body [1–5]. The polluted condition of sediment is one of the important factors to evaluate the quality of lake water environment [6, 7]. So, it is great significance to study the endogenous pollution release of heavy metal in lake water environment through the characteristics, and risk of heavy metal pollution was assessed in lake sediment.

Hengshui Lake is located in Hengshui City, Hebei Province, with an area of about 75 km². It is a typical inland fresh water lake. It is the main source of drinking water and industrial and agricultural production in Hengshui City and its surrounding areas. It is also a gathering place of animals and plants in the north temperate zone and a transit place for rare and endangered migratory birds. The maximum storage capacity is 188 million m³. It is the first National Wetland Nature Reserve in North China Plain.

Hengshui Lake is divided into East Lake and West Lake. The West Lake covers an area of about 32.5 km², with scattered water surface including many fish ponds and a natural pond. Due to historical reasons, there is a risk of heavy metal enrichment in sediment. In recent years, there have been studies on the pollution characteristics and ecological risk of heavy metal elements in the sediment of Hengshui Lake [8–11] and mainly focusing on the East Lake, while the study on the West Lake of Hengshui Lake has not been reported. In this study, the sediment of the West Lake of Hengshui Lake has been sampled and analyzed, and heavy metal pollution in sediment has been evaluated by using the geoaccumulation index (I_{geo}) method, so as to provide scientific basis for the effective control of heavy metal pollution, ecological environment protection, and risk management and control of Hengshui Lake.

2. Materials and Methods

2.1. Sampling Point Setting. The water area of the West Lake of Hengshui Lake is relatively scattered, and the distribution is uneven including many fish ponds and a natural pond. Therefore, according to the geographical location of the West Lake of Hengshui Lake, 21 sampling points had been set up in the West Lake of Hengshui Lake, including 20 fish ponds and 1 natural pond. The study area is located at longitude 115.5511726–115.580819°E and latitude 37.56968–37.637332°N.

2.2. Sample Collection and Analysis. According to the field investigation of the sediment and the disturbance in the West Lake of Hengshui Lake, 21 sampling points were selected in the West Lake of Hengshui Lake. The water depth of the sampling points is 1–5 M. The TC-600 the grab dredger was used to collect the sediment samples with the depth of 0–50 cm, the sampling area was 50 × 50 cm², and the sampling points were located by GPS, July 15–17, 2019. The sediment volume of each sampling point was about 1–2 L. The collected sediment samples were sealed and stored in polyethylene plastic bags and transported back to the laboratory for low temperature storage.

The sediment samples were air-dried. The dried sediment samples were homogenized with an agate mortar and sieved in a 0.5 mm mesh nylon sieve to obtain a fine homogeneous powder in the laboratory. Then, the samples were dried in an oven at 105°C to constant weight for the experiment.

The sediment samples were digested by a microwave digester (Model Mars6, CEM, U.S.A). The contents of Cr,

Zn, Pb, Cu, Cd, and Sb were determined by the atomic absorption spectrometry (Model TAS-990, Beijing Puxi General Instrument Co., Ltd., China), and the contents of Hg and As were determined by the atomic fluorescence spectrometry (Model SA7/5, Beijing Puxi General Instrument Co., Ltd., China).

2.3. Data Processing and Assessment Methods. In 1969, German scholar Mulr proposed the geoaccumulation index (I_{geo}) method [12], which was widely used to evaluate heavy metal pollution in water and sediment. Therefore, the geoaccumulation index method has been used to evaluate the heavy metal pollution degree of the West Lake of Hengshui Lake in this study.

The calculation formula of the geoaccumulation index method is expressed as

$$I_{geo} = \log\left(\frac{C_i}{kB_i}\right), \quad (1)$$

where C_i is the content of the element i in sediment (unit: mg/kg), and B_i is the geochemical background value of the element i . In this study, the background value of soil heavy metal elements content in Hebei Province (BVSH) [13] was used as the reference value. Coefficient k is the rectification coefficient due to the difference of the regional background value, generally 1.5. According to the value of I_{geo} , the heavy metal pollution degrees are divided into 7 classes (Table 1).

2.4. Statistical Analysis. The experimental data were processed by Excel software and were plotted by ArcGIS 10.3 software.

3. Results and Discussion

3.1. Distribution Characteristics of Heavy Metal Elements in the Sediment of the West Lake of Hengshui Lake. The contents of heavy metal elements in the sediment of the West Lake of Hengshui Lake are given in Table 2. Based on the background value of the soil heavy metal elements content in Hebei Province (BVSH), the pollution of eight heavy metal elements in the sediment of the West Lake of Hengshui Lake was evaluated. In natural ponds, the contents of the other seven heavy metal elements were all lower than BVSH except for Cr.

In the fish ponds sediment, only the average contents of Zn and Sb were lower than BVSH. In all sampling points, the contents of Sb were all lower than BVSH, while the contents of Zn were slightly higher than BVSH at 7 sampling points. The contents of Cr, Pb, Cu, Cd, Hg, and As were higher than BVSH. The average contents of Cd, Hg, and Pb were 2.37, 2.24, and 2.00 times of BVSH, respectively. It indicated that the pollution of Cd, Hg, and Pb in the sediment of fish ponds in the West Lake of Hengshui Lake was relatively serious. The average contents of Cu, Cr, and As were 1.72, 1.47, and 1.47 times of BVSH, respectively. It indicated that there was slight pollution of Cu, Cr, and As in the sediment of fish ponds in the West Lake of Hengshui Lake.

TABLE 1: I_{geo} and classification of sediment pollution degree.

I_{geo}	≤ 0	0~1	1~2	2~3	3~4	4~5	>5
Class	0	1	2	3	4	5	6
Pollution degree	Uncontaminated	Uncontaminated to moderately contaminated	Moderately contaminated	Moderately to heavily contaminated	Heavily contaminated	Heavily to extremely contaminated	Extremely contaminated

TABLE 2: Contents of heavy metal elements in the sediment at various sampling points in the West Lake of Hengshui Lake (mg/kg).

Sampling point	Longitude (°E)	Latitude (°N)	Cr	Zn	Pb	Cu	Cd	Hg	As	Sb
1	115.57972	37.637332	110.8	81.4	45.9	39.5	0.22	0.067	20.8	0.19
2	115.580235	37.632706	96.3	64.2	38.6	44.7	0.13	0.092	16.4	0.08
3	115.580819	37.625911	128.6	82.3	58.9	63.1	0.37	0.112	23.2	0.13
4	115.577401	37.615455	74.7	53.8	25.6	36.5	0.19	0.043	14.4	0.07
5	115.578115	37.613281	86.4	62.7	45.1	29.9	0.13	0.051	13.8	0.11
6	115.577711	37.61342	71.3	58.5	31.6	40.3	0.17	0.038	15.3	0.09
7	115.576741	37.613887	88.6	71.5	28.9	31.3	0.16	0.042	14.9	0.15
8	115.57612	37.613968	94.2	58.7	37.6	48.8	0.18	0.097	18.1	0.12
9	115.57448	37.614382	102.1	79.5	50.8	39.6	0.15	0.093	22.6	0.16
10	115.572681	37.608833	79.4	51.3	29.8	31.2	0.11	0.082	16.2	0.06
11	115.570792	37.614233	81.5	69.6	38.7	34.1	0.22	0.098	15.5	0.09
12	115.575772	37.608444	86.3	75.2	26.5	22.3	0.14	0.049	13.9	0.05
13	115.575105	37.609114	78.6	79.7	31.4	32.8	0.18	0.055	14.8	0.07
14	115.569049	37.607871	139.7	79.5	68.3	59.5	0.35	0.151	28.3	0.31
15	115.5511726	37.56968	162.6	95.8	76.4	53.1	0.48	0.134	30.4	0.26
16	115.573043	37.596982	103.6	62.1	38.6	23.3	0.29	0.081	17.4	0.12
17	115.570848	37.592124	115.9	76.4	53.4	31.4	0.32	0.126	25.8	0.14
18	115.570396	37.591182	97.1	63.2	50.8	29.6	0.21	0.064	30.7	0.11
19	115.569973	37.587342	127.5	87.6	46.1	33.2	0.34	0.087	28.2	0.35
20	115.571514	37.577032	89.3	58.4	35.7	23.8	0.12	0.054	19.7	0.09
Average			100.725	70.570	42.935	37.400	0.223	0.081	20.020	0.138
Natural pond	115.578324	37.615915	61.9	67.3	18.6	16.7	0.13	0.029	8.2	0.07
The background value of the soil in Hebei Province			68.3	78.4	21.5	21.8	0.094	0.036	13.6	1.22

The results showed that the contents of Cr, Zn, Pd, Cu, Cd, and Hg were 71.3–162.6 mg/kg, 51.3–95.8 mg/kg, 25.6–76.4 mg/kg, 22.3–63.1 mg/kg, 0.11–0.48 mg/kg, and 0.038–0.151 mg/kg in the sediment of fish ponds in the West Lake of Hengshui Lake, respectively. The contents of all sampling points were lower than the screening values of soil pollution risk of agricultural land in soil environmental quality: risk control standard for soil contamination of agricultural land (trial) (GB 15618-2018)[14].

The contents of As were 13.8–30.7 mg/kg, and the 14th, 15th, 17th, 18th, and 19th sampling points were higher than the screening value of soil pollution risk, but lower than the risk control value in GB 15618-2018.

The contents of Sb were 0.05–0.35 mg/kg. Since there are no relevant contents standard of Sb in GB 15618-2018, the contents of Sb were analyzed in soil environmental quality: risk control standard for soil contamination of development land (trial) (GB 36600-2018) [15]. The content of each sampling point was lower than the screening value of soil pollution risk of development land in GB 36600-2018.

3.2. Pollution Assessment by the Geoaccumulation Index (I_{geo}).
The results of I_{geo} of heavy metal elements in the sediment of the West Lake of Hengshui Lake are given in Table 3. It showed that I_{geo} of eight heavy metal elements in natural pond was all less than 0, which can be regarded as uncontaminated in natural pond.

In the fish ponds sediment, the I_{geo} values of Zn and Sb in all sampling points were less than 0, as given in Table 3, which could be regarded as uncontaminated. The areas with higher I_{geo} values of Zn and Sb concentrated in the south of the West Lake of Hengshui Lake, as shown in Figure 1 (the black spots are fish ponds, and the black regular triangular is natural pond), are adjacent to Jizhou District of Hengshui City. The higher contents of Zn and Sb may be related to high population density and more social activities of human beings.

The average values of I_{geo} about Cr, Zn, As, and Sb were less than 0 in all sampling points of the fish ponds. The average I_{geo} value of Cr was -0.0594 . But the I_{geo} values of seven sampling points were higher than 0, and the I_{geo} values

TABLE 3: I_{geo} of heavy metal elements in the sediment at various sampling points in the West Lake of Hengshui Lake.

Sampling point	Cr	Zn	Pb	Cu	Cd	Hg	As	Sb
1	0.113037897	-0.530787361	0.509194993	0.272562018	0.641808361	0.311201688	0.028014376	-3.267772325
2	-0.089312281	-0.873242858	0.259301687	0.450984196	-0.117183539	0.768674454	-0.314873337	-4.515699838
3	0.327970658	-0.514923724	0.868968474	0.948349369	1.391830108	1.05246742	0.185555653	-3.81526012
4	-0.455739836	-1.128209982	-0.33315535	0.158605828	0.430304256	-0.328622747	-0.502500341	-4.708344916
5	-0.245816767	-0.907350712	0.483828273	-0.129145151	-0.117183539	-0.08246216	-0.563900885	-4.05626822
6	-0.522946003	-1.00737953	-0.029374602	0.301489203	0.269839584	-0.506959989	-0.415037499	-4.345774837
7	-0.20954138	-0.717872913	-0.158229668	-0.063127979	0.182376742	-0.362570079	-0.453256822	-3.608809243
8	-0.121121019	-1.002455652	0.221433501	0.577590512	0.352301744	0.84502534	-0.172579455	-3.930737338
9	-0.004937118	-0.564861295	0.655529336	0.276209795	0.089267338	0.784271309	0.14775362	-3.515699838
10	-0.367709072	-1.196857329	-0.11398683	-0.067744607	-0.358191639	0.602664502	-0.332575339	-4.930737338
11	-0.33004802	-0.756728849	0.263034406	0.060481104	0.641808361	0.859822342	-0.396300937	-4.345774837
12	-0.24748752	-0.645083493	-0.283306801	-0.552246926	-0.010268335	-0.140177658	-0.553484269	-5.193771743
13	-0.382318767	-0.561236431	-0.038534601	0.004405179	0.352301744	0.026472211	-0.462971976	-4.708344916
14	0.447412036	-0.564861295	1.082586418	0.863599033	1.311659759	1.483517237	0.472232901	-2.561503528
15	0.666407273	-0.295790499	1.244273478	0.699421225	1.767339243	1.311201688	0.575502171	-2.81526012
16	0.016104019	-0.921222887	0.259301687	-0.488960681	1.040357738	0.584962501	-0.229481846	-3.930737338
17	0.177960582	-0.622243517	0.727540581	-0.058526077	1.182376742	1.222392421	0.338801913	-3.708344916
18	-0.077376784	-0.895891597	0.655529336	-0.14369346	0.574694165	0.245112498	0.589669503	-4.05626822
19	0.315577263	-0.424885285	0.51546759	0.021892606	1.269839584	0.688055994	0.46712601	-2.386416821
20	-0.198187904	-1.009847786	0.146624914	-0.458329062	-0.232660757	3.20343E - 16	-0.050373523	-4.345774837
Average	-0.059403637	-0.75708665	0.346801341	0.133690806	0.533130883	0.468252449	-0.082134004	-3.937365064
Natural pond	-0.218821314	-0.242392258	-0.239016775	-0.291831282	-0.03527576	-0.269995762	-0.395816315	-1.41735305

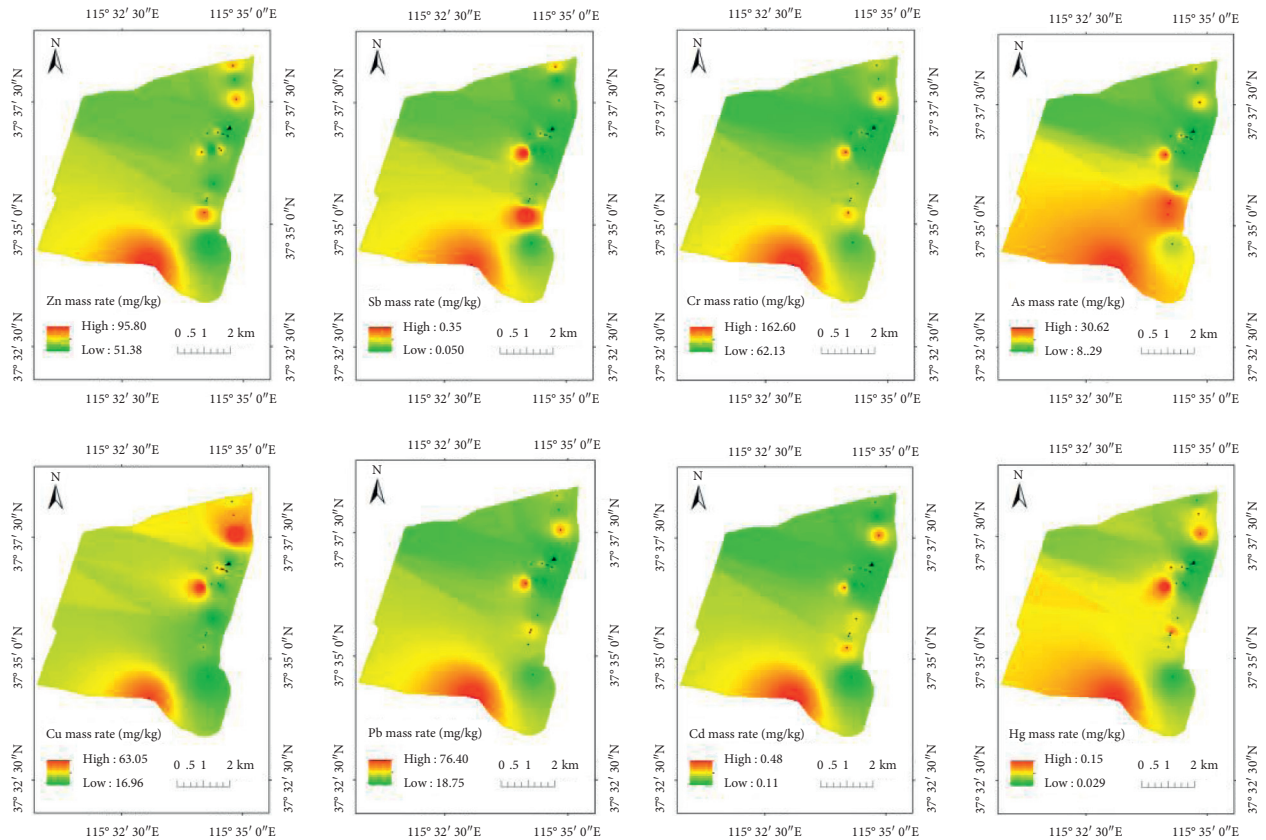


FIGURE 1: Spatial distribution of contents of 8 kinds of heavy metal elements in sediment at 0–50 cm depth in the West Lake of Hengshui Lake.

of Cr were 0.0161–0.66641, so the pollution class was 1. It indicated that the seven sampling points were uncontaminated to moderately contaminated by Cr.

The average I_{geo} values of As was -0.0821 in the fish ponds. But the I_{geo} values of 8 sampling points were higher than 0, and the I_{geo} values of As were 0.02801–0.58067, so the pollution class was 1. It indicated that the eight sampling points were uncontaminated to moderately contaminated by As. Similarly, the areas with higher I_{geo} values of Cr and As also concentrated in the south of the West Lake of Hengshui Lake, that is, the higher contents of Cr and As may be related to high population density and more human social activities too.

The average I_{geo} values of Pb, Cu, Cd, and Hg were higher than 0 in the fish ponds. The average I_{geo} value of Pb was 0.3468. The I_{geo} values of six sampling points were less than 0, and the I_{geo} values of other sampling points were 0.14662–1.24427. The I_{geo} values of the 14th and 15th sampling points were higher than 1, so the pollution class was 2. It indicated that the two sampling points were moderately contaminated by Pb. The I_{geo} values of the other 12 sampling points were 0–1, and the pollution class was 1. It indicated that the twelve sampling points were uncontaminated to moderately contaminated by Pb. Therefore, the pollution degree of Pb was moderately contaminated in general in the fish ponds. The areas with a higher I_{geo} value of Pb also concentrated in the south of the West Lake of Hengshui Lake, which means that the higher content of Pb was also related to the high population density and more human social activities.

The average I_{geo} value of Cu was 0.13369 in the fish ponds. The I_{geo} values of 8 sampling points were less than 0, and the other sampling points were 0.00441–0.94835. The I_{geo} values of these 12 sampling points were 0–1, and the pollution class was 1. It indicated that the twelve sampling points were slightly polluted. So, the pollution degree of Cu was uncontaminated to moderately contaminated in general in the fish ponds. The areas with a high I_{geo} value of Cu were scattered. The highest I_{geo} value was in the northeast corner of the West Lake. It is the junction of Hengshui City and the East Lake and the West Lake of Hengshui Lake, where the traffic flow is large and the population is concentrated. Therefore, it may be related to more human social activities and automobile exhaust.

The average I_{geo} value of Cd was 0.53313 in the fish ponds. The I_{geo} values of 5 sampling points were less than 0. The other sampling points were 0.08927–1.76734. The I_{geo} values of the 3th, 14th, 15th, 16th, 17th, and 19th sampling points were higher than 1, and the pollution class was 2. It indicated that the six sampling points were moderately contaminated. The I_{geo} values of the other 9 sampling points were 0–1, and the pollution class was 1. It indicated that the nine sampling points were uncontaminated to moderately contaminated. Therefore, the pollution degree of Cd was moderately contaminated in general in the fish ponds. The areas with a high I_{geo} value of Cd still concentrated in the south of the West Lake of Hengshui Lake, that is, the high contents of Cd were also related to the high population density and more human social activities.

The average I_{geo} value of Hg was 0.46825 in the fish ponds, and the I_{geo} values of 5 sampling points were less than 0. The I_{geo} values of other sampling points were 3.2×10^{-16} –1.48352. The I_{geo} values of the 3th, 14th, 15th, and 17th sampling points were higher than 1, and the pollution class was 2. It indicated that the four sampling points were moderately contaminated. The I_{geo} values of the other 11 sampling points were 0–1, and the pollution class was 1. It indicated that the eleven sampling points were uncontaminated to moderately contaminated. Therefore, the pollution degree of Hg was moderately contaminated in general in the fish ponds. The areas with a high I_{geo} value of Hg were scattered, mainly concentrated in the high-population density areas such as villages and around the city. So, it was also related to more human social activities.

4. Conclusion

- (1) In natural ponds, the contents of the other seven heavy metal elements were all lower than BVSH except for Cr, and the contents of eight heavy metal elements were all lower than the soil risk screening value of agricultural land in GB 15618-2018 or the soil pollution risk screening value of development land in GB 36600-2018.
- (2) The average contents of Cr, Zn, Pb, Cu, Hg, and As were higher than BVSH except for Zn and Sb in sediment of the fish ponds at various sampling points in the West Lake of Hengshui Lake. It showed a small amount of heavy metal elements pollutants.

In the fish ponds, the contents of Cr, Zn, Pb, Cu, Cd, and Hg were all lower than the standard of the soil risk screening value of agricultural land in GB 15618-2018. The contents of As in the sediment samples were 8.2–30.7 mg/kg. The contents of As in 5 sampling sites were higher than the screening value of soil pollution risk of agricultural land, but lower than the risk control value in GB 15618-2018. The contents of Sb were 0.05–0.35 mg/kg, which was lower than the screening value of soil pollution risk of development land in GB 36600-2018.

- (3) The results of I_{geo} pollution assessment showed that the sediment samples of the fish ponds in the West Lake of Hengshui Lake were mainly polluted by Cr, Pb, Cu, Cd, Hg, and As. And the pollution degrees of Cd, Pb, and Hg were moderately contaminated in general, the pollution degree of Cu was uncontaminated to moderately contaminated in general, and the pollution degree of Cr and As was uncontaminated to moderately contaminated in some sampling sites. While in the sediment of natural ponds, the I_{geo} values of Cr, Zn, Pb, Cu, Cd, Hg, As, and Sb were -1.41735305 to -0.03527576 , which could be regarded as uncontaminated.

The heavy metal pollution in the sediment of the West Lake of Hengshui Lake mainly concentrated in the southern edge area, which is close to Jizhou District of Hengshui City. It may be related to the high population density and more

human social activities. Therefore, it is necessary to strengthen the discharge control of heavy metal pollutants, the treatment of heavy metal pollutants in sediment, and the long-term monitor of heavy metal pollutants in the sediment. In addition, the analysis showed that the heavy metal pollution in the sediment of the West Lake of Hengshui Lake was mainly concentrated in the fish ponds. There was no heavy metal pollution in the natural pond. So, heavy metal pollution in the fish ponds may be due to the introduction of feeding [16, 17]. Therefore, the water environment of the West Lake of Hengshui Lake can be effectively improved by cleaning the sediment of fish ponds and “returning fishing to wetland.” In the future, several aspects of research should be reinforced, such as the correlation study in the heavy metal pollution in between the West Lake of Hengshui Lake and the surrounding environment, the association of heavy metal pollution between sediment and water in the West Lake of Hengshui Lake, and the comparison of heavy metal pollution between East Lake and West Lake in Hengshui Lake. In addition, the emphasis should be placed on the detection of heavy metal content in sediment, water, and surrounding soil in the Hengshui Lake region.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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