Contamination and Health Risk Assessment of Heavy Metal Zn in Three Riverine Animals

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Abstract: In the context of black smelly rivers and urban pollution control, heavy metal pollution of river sediments has attracted widespread attention. Heavy metals can accumulate in the sediment through hydrolysis and complexation, and cause secondary pollution through diffusion and migration. River animals play an important role in river ecosystems, and their feeding, excretion and disturbance activities can have a significant impact on the transport and transformation of heavy metals in the sediment. This paper investigates the effects of river animals on the transport and transformation of Zn, typical heavy metals in the sediment, and evaluates the contamination and risk of the sediment and river animals before and after the experiment.

1 INTRODUCTION

The environmental management of black smelly rivers in China is currently attracting widespread attention, and heavy metal pollution of river ecosystems is becoming an increasingly serious problem under the constant influence of natural and human factors. Through adsorption, hydrolysis and co-precipitation, heavy metals can mostly combine with specific ions in water to form stable complexes that accumulate in the water column and substrate, thus turning the substrate into the main body carrying heavy metal pollutants and making a potentially threatening source of internal pollution within the river ecosystem (1). The migration, trans formation and release of heavy metals at the substrate-water interface can cause secondary pollution of water bodies, adversely affect the life activities of aquatic organisms and cause further deterioration of the water environment, endangering human life and health. According to the relevant surveys, many well-known or unknown rivers in China have environmental pollution problems of large and small scale (2). The evaluation methods of comprehensive index method, potential hazard index method, ground accumulation index method and root mean square pollution index method will be used to explore the changes in the degree of heavy metal pollution in the substrate and animals before and after the experiment. The health risk assessment method and the target risk factor method will be used to measure the potential health risk to the environment and the exposed population from heavy metals in the substrate and animals before and after the experiment.

2 Materials and Methods

2.1 Sediment Sample Collection and Pretreatment

The sediment was collected from the Hejiagou section of a first-order tributary of the Songhua River, which was located near a small industrial park. After 2 d of resting, the substrate was thawed and homogenized by mechanical mixing, and then introduced into each experimental unit, and dechlorinated water was added against the wall to avoid artificially causing large substrate stirring, and the substrate was allowed to equilibrate with water sedimentation for 48 h (Yuan, 2021).

2.2 River Animals and Pretreatment

In this study, carp were selected for the overlying water ecotone, mudskipper for the surface sludge ecotone, and mussels for the sediment sludge ecotone as the experimental subjects. The mussels were firstly brushed with a soft brush to clean the mud and sand attached to the surface of the mussels, and then the carp, loach and mussels were temporarily kept in dechlorinated tap water for 48 h without feeding, and the water was changed at 12 h intervals to wash away any possible residual heavy metals on the surface and in their bodies (Chen, 2022).

2.3 Experimental Index Detection and Evaluation Method of Heavy Metal Contamination Risk in Animals of Each Ecological Site

Reference to related literature (Liang, 2022).

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3 EVALUATION OF HEAVY METAL POLLUTION REDUCTION IN RIVER SEDIMENTS

3.1 Evaluation of Integrated Heavy Metal Pollution Index for River Sediment

In this study, heavy metal contamination was evaluated in the river substrate during a 56-day experimental period (Chen, 2022). The single factor contamination indices for Zn in the control, carp, loach and mussel tank substrates and the total environmental quality indices were calculated as shown in Figure 1 below.

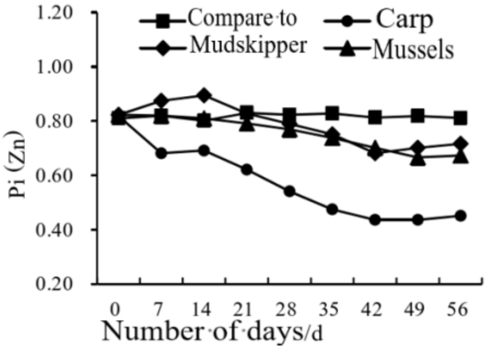

Figure 1. Characteristics of the single-factor contamination index of sediment heavy metals

As can be seen from Figure 1, The single-factor pollution indices of Zn in the control group, carp group, mudskipper group and mussel group were all in the low pollution level, among which the pollution index of Zn in the control group did not fluctuate significantly, the pollution index of Zn in the carp group decreased the most, the pollution index of Zn in the mussel group decreased the second most, and the pollution index of Zn in the mudskipper group decreased the least.

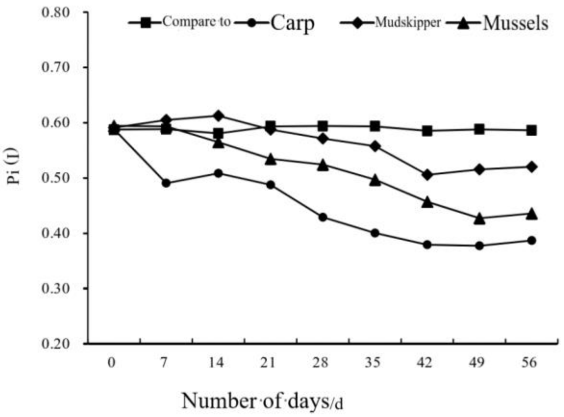

Figure 2. Characteristics of the variation of the total environmental quality index of sediment heavy metals

According to the analysis in Figure 2, the total environmental quality index of heavy metals in the substrate changed from having an impact on the environment in the control group; to being within the permissible range in the carp group; to having an impact on the environment in the loach group; and to being within the permissible range in the mussel group. In general, there was no significant change in the single factor pollution index and total environmental quality index in the control group, while the single factor pollution index and total environmental quality index of different heavy metals in the carp, loach and mussel groups decreased to different degrees, indicating that heavy metals in the substrate were transported to different degrees during the 56-day experiment.

3.2 Evaluation of Heavy Metal Accumulation Index in River Sediments

The formulae for the Geo accumulation Index (GI) method of evaluating heavy metals in river sediments (Cai, 2022), the GI method usually uses the average composition of the world standard shale as the reference value for calculation, therefore the geochemical background values of shale-type heavy metals in Table 2 will also be used as the geochemical background values, and the GI pollution classification criteria are shown in Table 1.

Table 1. Land Accumulation Index Grading Criteria

Grading	I_{geo}	Pollution level
1	I_{SQJ}<0	None
2	$0 \leq I_{SQJ} < 1.0$	Medium-None
3	$1.0 \leq I_{SQJ} < 2.0$	Medium
4	$2.0 \leq I_{SQJ} < 3.0$	Strong-Medium
5	$3.0 \leq I_{SQJ} < 4.0$	Strong
6	$4.0 \leq I_{SQJ} < 5.0$	Very strong-strong
7	$I_{SQJ} \geq 5.0$	Very strong

3.3 Evaluation of Potential Ecological Pollution Indices for River Substrates

The calculation formula (Zeng, 2022) of the integrated heavy metal pollution index evaluation method for river bottom sediment, the evaluation standard value of heavy metal uses the risk screening value of paddy field in Table 1; the toxicity coefficient of heavy metal is shown in Table 2; the classification of potential ecological pollution risk index is shown in Table 3.

Table 2. Toxicity factors for heavy metals in substrates

Heavy metals	Cr	Pb	Zn	Cu
T_r^i	2	5	1	5

Table 3. Classification of substrate heavy metal ecological pollution risk index

Individual Heavy Metals Potential Ecological Risk IndexE_r^i	Individual Heavy Metals Potential Biological Hazard Ecological hazard level	Total Potential Ecological Risk Index for Heavy MetalsI_{RI}	Total potential ecology of heavy metals hazard level
$E_r^i < 40$	Minor ecological hazards	$I_{RI} < 150$	Minor ecological hazards
$40 \leq E_r^i < 80$	Moderate ecological hazard	$150 \leq I_{RI} < 300$	Moderate ecological hazard
$80 \leq E_r^i < 160$	Strong ecological hazards	$300 \leq I_{RI} < 600$	Strong ecological hazards
$160 \leq E_r^i < 320$	Very strong ecological risk	$600 \leq I_{RI} < 1200$	Very strong ecological risk
$E_r^i \geq 320$	Very strong ecological hazard	$I_{RI} \leq 1200$	Very strong ecological hazard

In this study, the pH distribution of the substrate in the control, carp, Loach and Mussel group ranged from 7.44 to 7.85. The ecological pollution risk indices for Zn in the control, carp, Loach and Mussel group were obtained by selecting the corresponding risk screening values according to the pH of each substrate sample (Li, 2022).

3.4 Risk Assessment of Heavy Metal Exposure in River Sediments

The formulae for the non-carcinogenic risk index evaluation method (Wang, 2022) for heavy metals in river sediments, with the values for each parameter taken from the recommended values in the Benchmark for Environmental Risk Assessment of Soil in Industrial Enterprises and partly from the estimated values determined by references, are shown in Tables 4 to 6.

Table 4. Human skin contact parameters

FC	SA	AF	AED	CF
1	2550	0.09	0.01	106

Table 5. Human exposure parameters

BW	AT is not carcinogenic	ED	EF
55.9	25550*	40	55.9

Table 6. Toxicity data values for heavy metal elements

Element	Cr	Pb	Zn	Cu
Rf D	0.005	0.0035	0.3	0.038

The non-carcinogenic risk indices of heavy metals Zn in substrates (Wei, 2020) and organisms were analyzed over time by means of a 56-day ecological simulation experiment (Yan, 2019), and the calculated results were derived.

4 Evaluation of the risk of heavy metal contamination in riverine animals at various ecological sites

4.1 Root Meaning Square Integrated Contamination Assessment of Heavy Metals in Riverine Animals at Various Ecological Niches

The formula for the integrated heavy metal pollution index evaluation method in ecological site river animals (Li, 2022), the evaluation criteria values for heavy metals using the risk screening values for paddy fields in Table 1, the single factor pollution index grading for heavy metals as shown in Table 3 and the root mean square integrated pollution index grading as shown in Table 7.

Table 7. Grading criteria for the combined heavy metal contamination index in animals

Grading	PI	Pollution level
1	$PI \leq 1.0$	Low pollution
2	$1.0 < PI \leq 2.0$	Medium pollution
3	$2.0 < PI \leq 3.0$	Higher pollution
4	$PI > 3.0$	High pollution

Regarding the limits of heavy metals in animals, the ecological risk evaluation of heavy metals in animals before and after the experiment was carried out in this study and the results were calculated as follows.

From the changes of the single-factor pollution index of heavy metal Zn, the single-factor pollution index of heavy metal in the three groups of organisms showed an overall increasing trend. The chromium single factor pollution indices of carp, loach and mussel were all in high pollution status, with the largest increase in the chromium single factor pollution index in the carp group and the same increase in the chromium single factor pollution index in the loach and mussel groups.

According to Figure 3, the RMSI of heavy metals in the three groups gradually changed from light to heavy pollution in the carp group, from light to heavy pollution in the loach group, and from no to heavy pollution in the mussel group during the 56-day experimental period. Overall, the mean square root contamination indices of all three groups increased to different degrees during the experimental period, indicating that all three groups were enriched in heavy metals to different degrees.

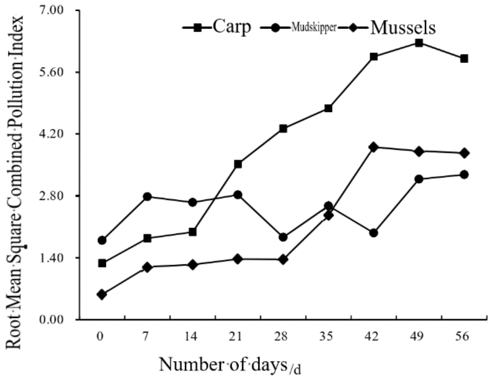

Figure 3. Characteristics of changes in the root mean square composite pollution index in three groups of animals

According to the analysis in Figure 4, in terms of the total risk index of heavy metals in the three groups of organisms, there was no significant health risk in the carp, loach and mussel groups during the 56-day experimental period.

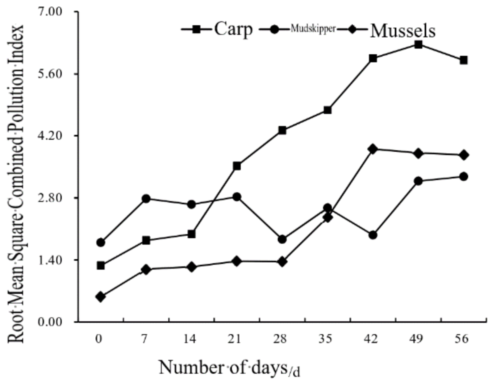

Figure 4. Characteristics of changes in the total risk factor in the three groups of animals

5 Conclusion

The river sediments and river animals in the ecological simulation experiment were evaluated comprehensively by various pollution index evaluation methods and exposure health risk evaluation methods, and the following conclusions were drawn: During the experimental period, the heavy metal Zn pollution evaluation method was used to focus on the river sediments. The total environmental quality index of river sediments in the carp and mussel groups gradually changed from the state of environmental impact to the state within the environmental permissible range; the ground accumulation index of Zn in the carp group gradually changed from the state of moderate no pollution to the state of no pollution. The level of heavy metal pollution of river animals in different ecological niches varied from light pollution to heavy pollution for carp and loach, and from no pollution to heavy pollution for mussels.

6 Discussion

In this paper, we monitored the changes of environmental factors at the overlying water interface and the substrate interface, as well as the changes of heavy metal content and morphology at the overlying water interface, the substrate interface and the river animals of different ecological niches, and explored the differences of the influence of river animals at different ecological niches on environmental factors and heavy metals from the population level. We also evaluated the health risk of the sediment and river animals before and after the experiment, and explored the changes of heavy metal pollution in the sediment and river animals in each ecological status. The environmental behaviors of river animals in each ecological site were analyzed and compared in terms of their effects on the heavy metals in the sediment and themselves, so as to provide a reference for the selection of animal populations for the construction of biological communities with good effectiveness against heavy metals in the sediment in engineering applications.

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