Current Situation and Ecological Risk Analysis of Heavy Metal Pollution in Surface Sediments of Shenzhen Bay

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Abstract

In order to study the content characteristics, ecological effects and potential ecological risks of heavy metal Cd, Hg, As, Cu, Pb and Zn in surface sediments of Shenzhen bay, we conducted a site survey of Shenzhen bay on a voyage in July 2018. The results showed that the average contents of heavy metal Cu, Pb, Zn, Cd, Hg and As are 25.80, 21.83, 80.91, 0.28, 0.06 and 12.72mg/kg, respectively. The ecological effect evaluation showed that the content of As at 7 stations is between the effect range low (ERL) and effect range median (ERM), but occasionally has adverse ecological effects. The contents of Cu, Pb, Zn, Cd and Hg at all stations are all lower than ERL, with almost no adverse ecological effects. The analysis results of potential ecological risk showed that the potential ecological risk coefficient of Cd, Hg and As in the surface waters of Shenzhen bay is high, while that of Cu, Pb and Zn is relatively low. The coastal area of Shenzhen bay, close to the estuary, is a high potential ecological risk area.

Keywords

Shenzhen bay; Surface sediment; Heavy metal; Ecological risk.

1. INTRODUCTION

Heavy metal pollution is a severe and widespread environmental problem because of the bio-toxicity, non-biodegradable and bioaccumulation character of heavy metal.[1] Heavy metals interact strongly with proteins and enzymes in the human body, which can inactivate the proteins and enzymes, and then seriously affect the metabolic activities of the human body and the normal functioning of the body. Once the heavy metal has an acute or chronic toxic effect on benthic organisms, it will cause serious damage to the entire marine environment [2-4]. Due to the cumulative effect, heavy metal content is higher than the corresponding sea water. After entering the ocean, heavy metals are easy to be stored in seawater [5-6] and show a strong distribution pattern [7-8]. The sediment in marine environment is the main storage place of heavy metal, as the heavy metal in the water body can easily transfer from the water phase to the solid phase through precipitation, adsorption and complexation, and secondary pollution may be caused when the heavy metal suspends and dissolves into the water again. [9]. Therefore, it is an important indicator to evaluate marine environmental pollution by investigating the content characteristics and ecological effects of heavy metals in marine waters.

Gulf is significant and representative in the study as it is the main channel of industrial waste transportation to sea from the land and one of the areas most affected by human activities. Thus, the heavy metal pollutants generated by human activities around the gulf are likely to cause heavy metal pollution in sediment. Shenzhen bay is located in the eastern pearl river mouth, between Shenzhen and Hong Kong, covering an area of 112 km2. There are many rivers running into sea in Shenzhen bay, and Shenzhen is a mega-city with rapid industrialization and dense urban population. Industrial wastewater and domestic sewage carry a large number of heavy metal pollutants into Shenzhen bay. Moreover, the exchange capacity of seawater in Shenzhen

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bay is poor, and the shoreline is in the transition zone between land and sea. Heavy metals generated by natural factors and human activities tend to attach to suspended particulate matter and subsequently fall into seawater [10]. Therefore, it is particularly important to monitor and evaluate the environmental quality of sediment in Shenzhen bay. Based on the field survey data of Shenzhen bay in July 2018, this study analysed the ecological effects and potential ecological risks of the six heavy metals including Cd, Hg, As, Cu, Pb and Zn in the surface sediments in Shenzhen bay, summarize the characteristics of local water pollution, and evaluate the potential ecological risk of heavy metals, providing scientific and statistical basis and theoretical support for the marine ecological environment protection and restoration in this area.

2. MATERIALS AND METHODS

2.1. Sampling Station and Time

The survey area is selected to be all located in Shenzhen bay, with a total of 9 survey stations. The survey was conducted in July 2018.

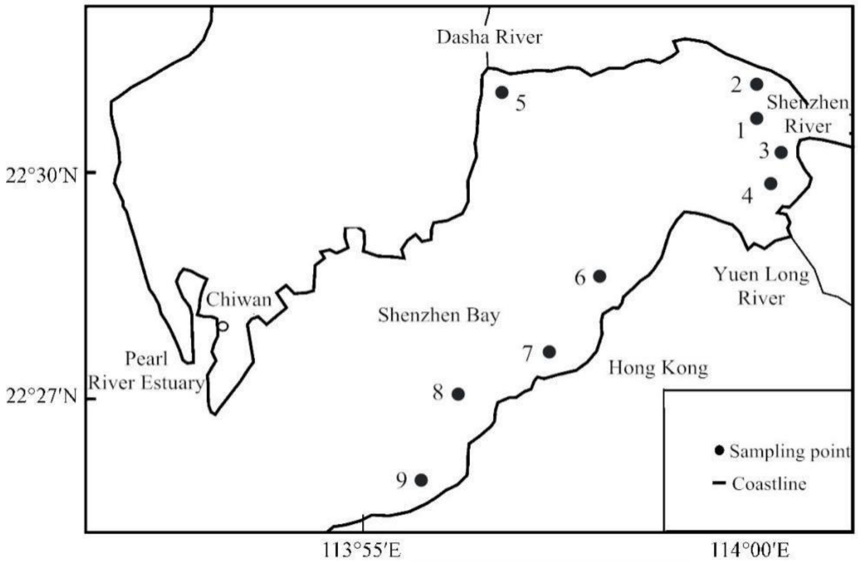

Fig 1. Study area and sampling stations

2.2. Determination of Elements and Analysis Method

The detection of heavy metals in samples includes Cd, Hg, As, Cu, Pb and Zn. Sampling, on-site treatment and analysis of samples are conducted according to the methods specified in the “specification for marine monitoring (GB17378.5-2007)[11].Cu, Pb, Zn and Cd are determined by atomic absorption spectrophotometry (PEAAS-900t, USA). Hg and As are determined by atomic fluorescence spectrometry (AFS-230E).

3. RESULT AND DISCUSSION

3.1. Heavy Metal Content

The measured values of heavy metal index content in surface sediments of Shenzhen Bay are shown in table 1. According to CSBTS (China State Bureau of Quality and Technical Supervision), 2002, the primary standards of Cu, Pb, Zn, Cd, Hg, As are 35.00, 60.00, 150.00, 0.50, 0.20, 20.00, and the secondary standard is 100.00, 130.00, 350.00, 1.50, 0.50, 65.00. The average values of Cd, Hg, As, Cu, Pb and Zn are 0.28, 0.06, 12.72, 25.80, 21.83 and 80.91mg/kg respectively, which are all lower than the standard value of category I of national marine sediment quality

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(GB18688-2002). The maximum values of these six heavy metal elements are all less than the standard value of citatory II of national marine sediment quality (GB18688-2002) [12]. The average values of heavy metal Cd, Pb, Zn and Cu contents are greater than the median value, while the average values of As and Hg contents are less than the median value. This indicates that the content distribution of Cu, Pb, Zn and Cd in Shenzhen bay is inclined to the high content direction, while the content distribution of As and Hg is inclined to the low content direction.

Table 1. Heavy metal content in surface sediments of Shenzhen bay unit: mg/kg

Statistical value	Cu	Pb	Zn	Cd	Hg	As
1	25.00	30.00	80.00	0.50	0.20	10.00
2	25.80	25.14	83.20	0.41	0.07	15.10
3	25.20	18.90	48.80	0.43	0.07	13.10
4	33.80	33.36	122.40	0.40	0.07	14.90
5	27.85	21.60	125.60	0.46	0.05	17.50
6	23.55	17.64	63.20	0.24	0.07	8.11
7	24.85	22.68	89.60	0.14	0.04	7.30
8	25.30	21.48	71.20	0.11	0.03	12.80
9	22.40	14.46	44.80	0.15	0.03	11.50
10	23.50	21.18	79.20	0.17	0.07	14.20
Mean	25.80	21.83	80.91	0.28	0.06	12.72
Maximum	33.79	33.37	125.85	0.46	0.07	17.50
Minimum	22.39	14.45	45.02	0.11	0.03	7.30
Median	25.21	21.45	78.84	0.24	0.07	13.10
Standard deviation	3.38	5.32	28.68	0.14	0.02	3.31
National Marine sediment category I standard (state oceanic administration,2002)	≤35.00	≤60.00	≤150.00	≤0.50	≤0.20	≤20.00
National Marine sediment category II standard (state oceanic administration,2002)	≤100.00	≤130.00	≤350.00	≤1.50	≤0.50	≤65.00

3.2. Evaluation of Ecological Effects of Heavy Metal

Heavy metal pollution can affect microflora, microbial process and ecological species in sediment, further affecting the structure and function of the ecosystem and ultimately bringing negative effects to the ecosystem [13].Effect range low (ERL) and Effect range median (ERM) were established by Long et al. [14], which is the sediment quality standard widely used in international environmental assessment. The heavy metal content in sediment can be divided into three regions according to the ecological effects of ERL and ERM. The heavy metal content is less than that of ERL, indicating that there are few adverse ecological effects. Heavy metal content is between ERL and ERM, indicating occasional adverse ecological effects. Heavy metal content is higher than ERM, which indicates that adverse ecological effects are often produced [15].

The comparison of heavy metal content and ecological effect concentration standard (ERL and ERM) of Shenzhen bay surface waters is shown in table 2. The contents of Cd, Hg, Cu, Pb and Zn are all lower than their ERL values, indicating that the impact of these five heavy metals on marine sediment ecological environment is relatively low. The content of As at 22.22% station is lower than that of ERL, and the content of As at 77.78% station is between ERL and ERM, suggesting that As occasionally produces adverse ecological effects and affects marine sediment environment. Therefore, in theory, As in the surface waters of Shenzhen bay would have an ecological impact on the sediment environment and benthic community, and we should pay enough attention to it.

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3.3. Evaluation of Ecological Risks of Heavy Metal

The potential ecological risk of heavy metals in the surface waters of Shenzhen bay is analysed and evaluated by the Hakanson potential ecological risk index method. Hakanson(Swedish scholar) proposed the potential ecological risk index method in 1980 [16], which fully considered the biological and ecological toxicity of pollutants, including the current and potential ecological risks [17].The regional geochemical background value of heavy metals is a key index in the study of ecological risk of heavy metals in sediments [18].We consider that the background value of elements in the study area is closer to the actual situation than the geochemical background value in normal shale. For this reason, this study used the research results by Feng muhua et al. [6] on background values of heavy metal Cd, Hg, As, Cu, Pb and Zn in Shenzhen bay sediments (see table 3) for reference. The calculation formula is as follows:

Table 2. Comparison of heavy metal content and ecological effect concentration standard of surface sediments in Shenzhen bay

Element	Content/mg·kg-1		Ecological effect concentration standard [14]		Percentage of sample over effect concentration /%		
	Minimum	Maximum	ERL	ERM	<ERL	ERL-ERM	>ERM
Cu	20.99	33.79	34	270	100(9/9)	0	0
Pb	14.45	33.37	46.7	218	100(9/9)	0	0
Zn	45.02	125.85	150	410	100(9/9)	0	0
Cd	0.11	0.46	1.2	9.6	100(9/9)	0	0
Hg	0.03	0.07	0.15	0.71	100(9/9)	0	0
As	7.30	17.50	8.2	70	22.22(2/9)	77.78(7/9)	0

$$E_r^i = T_r^i \times \frac{C_i}{C_o}; RI = \sum_{i=1}^{n} E_r^i$$

Where, RI is the potential ecological risk index of multiple heavy metal elements, Eri is the potential ecological risk coefficient of single heavy metal element, Ti is the heavy metal toxicity response factor, C is the measured value of heavy metal and Co is the background value. Ti of Cd, Hg, As, Cu, Pb and Zn is 30, 40, 10, 5, 5 and 1, respectively. The level of potential ecological risk assessment of heavy metals is shown in table 4.

Table 3. Heavy metal background value of surface sediments in Shenzhen bay mg/kg

Element	Cu	Pb	Zn	Cd	Hg	As
Background value	25	30	80	0.5	0.2	10

Table 4. Potential ecological risk assessment level of heavy metal

	Eri	Ecological risk level of single factor pollution	RI	Total potential ecological risk level
1	<40	Low	<150	Low
2	40~80	Medium	150~300	Medium
3	80~160	Heavy	300~600	Heavy
4	160~320	Heavier	≥600	Serious
5	≥320	Serious		

The calculation results of heavy metal potential ecological risk coefficient (Eri) and potential ecological risk index (RI) of surface sediments in Shenzhen bay are shown in table 5. In the

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study area, the Eri average range is 1.01~16.77, both less than 40. RI ranges from 33.24 to 66.93, with RI all less than 150.Further analysis revealed that Eri sequence is Cd>As>Hg>Cu>Pb>Zn, indicating that Cd, As and Hg are the main elements with potential impact on the ecological environment of Shenzhen bay. Among them, the Eri value of Cd is the largest, and the high value appears around station 1, 2, 3 and 4, indicating that the potential ecological risk of Cd in Shenzhen bay is relatively high near the estuary of Shenzhen river. The Eri value of As is higher at station 9, except around station 1, 2, 3 and 4. This indicates that the high potential ecological risk area of As increases the sea area at the estuary of dasha river besides the area overlapping with Cd. The high value of Eri in Hg appears in station 1, 2, 3, 4, 5 and 9, indicating that the high potential ecological risk area of Hg increases the sea area at the estuary of dasha river. Through analysis, we found that the high potential ecological risk areas of Cd, As and Hg are around station 5, 1, 2, 3, 4 and 9, which is located in Shenzhen bay near the estuary. The potential ecological risks of Cd, As and Hg are relatively small in station 6, 7 and 8 farther from the estuary. This suggests that pollutants from the cities around the river and sea may eventually be brought into Shenzhen bay through various channels. Therefore, the coastal area of Shenzhen bay, closer to the estuary, is a high potential ecological risk area for heavy metals.

Table 5. Heavy metal Eri and RI in surface sediments of Shenzhen bay

Station	Eri						RI
	Cu	Pb	Zn	Cd	Hg	As	
1	5.16	4.19	1.04	24.69	13.40	15.10	63.58
2	5.04	3.15	0.61	25.85	14.80	13.10	62.55
3	6.76	5.56	1.53	23.98	14.20	14.90	66.93
4	5.57	3.60	1.57	27.64	10.40	17.50	66.28
5	4.71	2.94	0.79	14.53	13.80	8.11	44.88
6	4.97	3.78	1.12	8.67	7.40	7.30	33.24
7	5.06	3.58	0.89	6.72	5.60	12.80	34.65
8	4.48	2.41	0.56	8.78	6.60	11.50	34.33
9	4.70	3.53	0.99	10.09	13.40	14.20	46.91
Range	4.48~6.76	2.41~5.56	0.56~1.57	6.72~27.64	5.60~14.80	7.30~17.50	33.24~66.93
Mean	5.16	3.64	1.01	16.77	11.07	12.72	50.37
Standard deviation	0.68	0.89	0.36	8.63	3.64	3.31	14.54

4. CONCLUSION

The heavy metal content in the surface waters of Shenzhen bay is relatively low. The average values of Cu, Pb, Zn, Cd, Hg and As are respectively 25.80, 21.83, 80.91, 0.28, 0.06 and 12.72mg/kg, which are all lower than the standard of category I of national marine sediment quality.

The analysis of the ecological response of heavy metals in the surface waters of Shenzhen bay showed that the contents of Cd, Hg, Pb, Cu and Zn are all lower than their ERL and have little impact on the ecological environment. As occasionally has negative ecological effects. In theory, As in the surface waters of Shenzhen bay would have an ecological impact on the sediment environment and benthic community. We should pay enough attention to it.

Cd, As and Hg are potentially harmful to the ecological environment of Shenzhen bay. The potential ecological risk coefficient of Cd, Hg and As in the surface waters of Shenzhen bay is higher. The potential ecological risk coefficient of Cu, Pb and Zn is relatively low. The coastal area of Shenzhen bay, close to the estuary, is a high potential ecological risk area.

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