Yangtze River: the potential ecological risk of heavy metals in sediment from 1996 to 2012

Xinyu Song, Lina Xu and Yanhui Dai*

Key Laboratory of Marine Environment and Ecology, Ministry of Education and College of Environmental Science and Engineering, Ocean University of China, Qingdao 266100, China
E-mail address: yanhui1437@163.com

Abstract. The Yangtze River is a typical river basin in China. As the third largest river in the world and closely related to the life of 4 hundred million people, the Yangtze River has attracted much attention. The heavy metal content of sediments is an important part to evaluate the heavy metal pollution in aquatic ecosystem. In this work, seven kinds of heavy metals including Cu, Hg, Pb, Zn, Cr, Cd and As were selected as the research objects, and the potential ecological risk index method was selected as the analysis method. Based on the results on the investigations of heavy metals in Yangtze River sediments in recent 20 years that we could find until 2016, we conducted a collection and analysis. The results showed that the potential ecological risk of these seven heavy metals in the Yangtze River Basin in the past 20 years had a low level. In addition, the ecological risk factors of Cd and Hg were significantly higher than other heavy metals, which should be paid attention in the future management and control work.

1. Introduction

Heavy metals are metals with a density greater than 4.5 g/cm³ and are commonly found in the environments, including beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), plumbum (Pb), hydrargyrum (Hg), nickel (Ni), argentum (Ag), thallium (Tl), zinc (Zn), aluminum (Al), barium (Ba), ferrum (Fe), manganese (Mn), molybdenum (Mo), cobalt (Co), titanium (Ti), vanadium (V), stibium (Sb), arsenic (As) and selenium (Se) and other heavy metals and metalloids. They are often considered as important factors causing environmental pollution. Heavy metals have highly toxic, are easy to accumulate and they are also difficult to be degraded [1-4]. Because the heavy metals are readily to be accumulated in various organisms [5-6], and be transferred in the ecosystem through the food chain, their pollution prevention and control is particularly significant.

Aquatic ecosystem is an important type of area in human activity. Not only because of human activities are affected, but also in turn affect the quality of human life and human health. Heavy metals can cause different degrees of water pollution through mining, exhaust emission, sewage irrigation and other channels. The famous Japanese Minamata disease, for example, heavy metal pollution of the water environment has caused serious harm to human health[7].

Sediment is an important food source and habitat of benthic organisms and overlying aquatic organisms [8-9]. So it is an important part of aquatic ecosystems. The sediments have large specific surface area [10] and contain active functional groups [11], which can adsorb heavy metal contaminants from natural water. If we only pay attention to the water quality of the surface water, we cannot control the aquatic ecosystem completely. In addition, studies have shown that the heavy metal pollutants absorbed on the sediments will be released again, thus causing secondary pollution to the
aquatic environment and biology [12]. So the harm caused by heavy metal in sediment demands more attention.

2. Materials and methods

2.1. Study area and sample collection
The Yangtze River is the third largest river in the world, with a total length of 6300km. As the basin has a population of 400 million and its economic development is extremely fast, the environmental impact of the Yangtze River is highly concerned. In this paper, we collected the literatures on heavy metals including Cu, Pb, Hg, Zn, Cd, Cr and As in the Yangtze River sediments from 1996 to 2012 and summed up. These 7 elements is mentioned in China prefered controlled pollutant in water, China's marine sediment quality standards (GB 18668-2002), surface water quality standards (GB3838-2002) and hygienic standard for drinking water (GB5749-2006). And the potential ecological risk assessment of heavy metals in different years was analyzed.

2.2. Analytical methods
The potential ecological risk index method is a relatively fast, simple and standard method proposed by the Swedish scientist HAKANSON in 1980 to evaluate the potential ecological risk of heavy metals[13].

Single metal pollution coefficient:

\[ C_f^i = \frac{C_s^i}{C_n^i}; \]

Potential Ecological Risk Coefficient of Single Metal:

\[ E_r^i = T_f^i \cdot C_f^i; \]

Comprehensive potential ecological hazard coefficient:

\[ RI = \sum E_r^i \]

Wherein, \( C_s^i \) represents concentration of heavy metals in sediment, \( C_n^i \) represents background value, \( T_f^i \) represents the toxicity coefficient of heavy metals, which are shown in Table 1. The potential ecological risk levels are shown in Table 2[14].

| Levels | Potential ecological risk | Code |
|--------|---------------------------|------|
| RI≤150 | Low                       | A    |
| 150<RI≤300 | Moderate              | B    |
| 300<RI≤600 | Considerable        | C    |
| 600<RI   | Very high                | D    |

Table 1. The background value and toxicity coefficient of heavy metals.

| Background value[15] | Cu  | Hg  | Pb  | Zn  | Cd  | Cr  | As  |
|-----------------------|-----|-----|-----|-----|-----|-----|-----|
| 30                    | 0.2 | 25  | 80  | 0.5 | 60  | 15  |
| Toxicty coefficient[16]| 5   | 40  | 5   | 1   | 30  | 2   | 10  |

3. Results
The potential ecological risk indices (RI) were calculated to assess pollution by 7 metals in sediments in the Yangtze River from 1996 to 2012. As shown in Table 3, the RI values of heavy metals in the Yangtze River sediment were basically all lower than 150, suggesting that most areas had low ecological risk from heavy metals. Therefore, the RI value in 2007 was ranging from 150 to 300, suggesting that most areas had moderate level from heavy metals in 2007. These results showed that the ecological risk level in the Yangtze River were almost low in the past 20 years.

We also found that from 1996 to 2012, two heavy metals showed obvious ecological risk than other heavy metals. What was shown in figure 2 has proved this. Cd and Hg, especially Hg, showed greater
potential ecological risk coefficient than Cu, Pb, Zn, Cr, As. In particular, the potential ecological risk coefficient of Cd was significantly higher than other heavy metals in 2007, and the potential ecological risk coefficient of Hg was higher than others in 2003. We supposed that in these two years the industrial emissions and other anthropogenic pollution led to this situation. Thus, we considered that Cd and Hg as the two elements most in need of attention when we talked about heavy metal pollution issues in sediment.

Table 3. Potential ecological risk index of heavy metals in the Yangtze River sediment.

| Year | RI     |
|------|--------|
| 1996 | 13.12/A|
| 2000 | 26.63/A|
| 2001 | 25.67/A|
| 2003 | 102.39/A|
| 2005 | 73.49/A|
| 2006 | 10.72/A|
| 2007 | 235.9/B|
| 2008 | 14.57/A|
| 2009 | 14.5/A|
| 2010 | 30.05/A|
| 2011 | 6.2/A|
| 2012 | 20.99/A|

Figure 1. Comparison of heavy metals in the Yangtze River sediments between 1996 and 2012.

4. Conclusion
These results showed that the ecological risk level in the Yangtze River were almost low in the past 20 years. We also considered that Cd and Hg as the two elements most in need of attention when we talked about heavy metal pollution issues in sediment.

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References
[1] Zhang C, Liu Q and Chen Y 2008 An Review:Toxity of Heavy Metals to Aquatic OrganismsLife Science Instruments
[2] Ghosh M and Singh S P 2005 A review on phytoremediation of heavy metals and utilization of its byproducts Applied Ecology & Environmental Research3(1)1-18
[3] Asmussen O 1997 Heavy metal concentrations in sediments from the coast of BahrainInternational Journal of Environmental Health Research7(1)85-93
[4] Tuncer G, Karakas T, Balkas T I, et al 1998 Land-based sources of pollution along the black sea coast of Turkey: Concentrations and annual loads to the black sea Marine Pollution Bulletin 36(6)409-423

[5] Qing L and Zijian W 1996 Research progress on the relationship between heavy metal morphology, biological toxicity and bioavailability Environmental Science 1996(1)89-92

[6] Hongxia Z, Yong Z and Zirong X Research progress on toxicity of heavy metals to aquatic animals Chinese Journal of Veterinary Medicine 28(4)13-18

[7] Jingsheng C and Jiayi Z 1992 Study on Heavy Metals in Water Environment in China China Environmental Science Press

[8] J.P.G.s, Yuduan W and Yiping Y 1984 Chemical oceanography Ocean Press

[9] Wurl O and Oubbard J P 2004 A review of pollutants in the sea-surface microlayer (SML): a unique habitat for marine organisms Marine Pollution Bulletin 48(11-12)1016–1030

[10] Rawlins B G, Turner G, Mounteney I, et al 2010 Estimating specific surface area of fine stream bed sediments from geochemistry Applied Geochemistry 25(9)1291-1300

[11] Gibson R N, Barnes M and Atkinson R J A 2001 Functional group ecology in softsediment marine benthos: the role of bioturbation Oceanogr Mar Biol Annu Rev 39 233-267

[12] Hulscher T E M T, Mol G A J and Lüers F 1992 Release of metals from polluted sediments in a shallow lake: quantifying resuspension Hydrobiologia 235-236(1)97-105

[13] Hakanson L 1980 An ecological risk index for aquatic pollution control a sedimentological approach Water Research 14(8)975-1001

[14] Wang Y, Yang Z, Shen Z, et al 2010 Assessment of heavy metals in sediments from a typical catchment of the Yangtze River, China Environmental Monitoring & Assessment 172(1-4)407-417

[15] Yi S, Qinglin M, Yunyong S, et al. 2011 Distribution and ecological risk assessment of heavy metals in sediments of the yangtze river estuary and its adjacent sea area Journal of Zhejiang Ocean University (Natural Science Edition) 30(2)107-112

[16] Hui Y, Guoguang C, Hongying L, et al. 2013 Heavy metal pollution and potential ecological risk assessment of major lake sediments in the lower Yangtze River Earth and Environment 41(2)