Comprehensive Pollution Analysis of Contaminated Sediment in an Urban River, China

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Abstract. Sediment pollution has been one of the most serious water pollution problems in urban rivers, called the ‘autogenous pollution’, which has also caused critical ecological risk to river as well as surrounding environment. Therefore, quantitative analysis of sediment pollution is of great importance to come up with a treatment scheme. In this study, comprehensive pollution analysis of contaminants has been conducted for various vertical stratifications using 86 columnar samples with depth of 3~4 m. Pollution assessments of organic matter, total nitrogen, total phosphorus, toxic substances and heavy metal elements were conducted. Then, the comprehensive pollution depths can be determined based on pollution assessment of each vertical layer, which shows that the maximum pollution depth can be up to 2.0 m, 3.0 m and 3.0 m for Reach A, Reach B and Reach C, respectively. The results has been used to determine the spatially changing thickness in environmental protection dredging in Maozhou River.

1. Introduction

Contaminated sediment is a sink of various contaminants through atmospheric sedimentation, wastewater discharge, rainwater leaching and so on. Conversely, contaminated sediment gives rise to water body by pollutant release [1]-[3]. As a result, the polluted sediment becomes the main pollution source to water body, called autogenous pollution. In recent papers, more attention has been paid to heavy metal elements pollution assessment [4]-[8]. However, contributions of other pollutants can’t also be ignored. As is known to us, freshwater with excess nitrogen, phosphorus and organic matter promotes microbial growth, causing oxygen depletion and destruction of the entire river ecosystem [9]. Toxic substances, usually referred to heavy metal elements, phthalate and PAHs, have very terrifying pathogenicity to human [10]-[12]. Therefore, comprehensive pollution analysis is necessarily significant to improve water quality.

Due to urbanization development, Maozhou (MZ) River has been one of the most polluted rivers in China. The water body looks like ink and gives off a bad smell, which has threaten surrounding environment and residents' health. Though a few of studies have revealed in the last twenty years that the heavy metal elements in the surface layer (30~60 cm) excess the threshold, which has brought about great environmental risk. However, existing studies are not enough to comprehensively reflect the pollution of sediments and then to guide environmental protection sediment dredging project.

Therefore, the main research content of this study is to reveal the pollution levels of sediment comprehensively, which provides reference to determine the pollution depths changing with space.
2. Study area and sample collection

2.1. Study area
MZ River is located in the northwest corner of Shenzhen City, of which there are about one main channel and 40 branches in the basin zone, finally running into the Pearl River Estuary (Figure 1). The reaches of Yangchong Sluice (YCS)-Pearl River Estuary and Shajing (SJ) River were investigated because they have been influenced by human activities in the process of urbanization and industrialization. Due to domestic and industrial sewage, the river sediment environment has been destroyed, and becomes black and odorous (Figure 2), which also becomes one of the main reasons causing black and odorous water.

![Figure 1. Distribution of studied river reaches in the river basin.](image)

![Figure 2. Contaminated sediment collected from MZ River.](image)

2.2. Sediment sample
Sediment samples were collected from three reaches through boring method from July to August 2016.

![Figure 3. Distribution of observed sections and points.](image)

The range of reach A is from confluence of MZ River and SJ River to YCS; the reach B is from confluence of MZ River and SJ River to Tantou; the reach C is from confluence of MZ River and SJ River to the Pearl River Estuary. Forty six sections and eighty six points were set along the three reaches (Figure 3). The space between every two sections is 300–400 m, which is about 100–200 m between every two points.
The position of each point were located by GPS precisely, of which the borehole depth is between 3~4 m. Therefore, Each borehole sample can be vertically divided into four layers from the surface to bottom, marked as layer I (0~1 m), layer II (1~2 m), layer III (2~3 m) and layer IV (>3 m).

3. Results and discussion

3.1. Pollution assessment of organic nutrients
Organic nutrients is often used to evaluate the fertility and eutrophication potential of sediment in lakes and rivers. Organic nutrients in sediment often include organic matter, total N and total P, of which pollution assessment can be conducted according to [13].

(1) Organic matter
For each reach, the content of organic matter decreases with sediment depth, of which the maximum average value is 39526 mg/kg (Figure 4(a)). Then the pollution index [14] can be calculated (Figure 4(b)). Obviously, the layers I~II of Reach B and layer I of Reach A suffer pollution with index greater than 0.5. Therefore, the average pollution depth is 2.0 m for Reach B and 1.0 m for Reach C.

![Figure 4. Pollution assessment of organic matter: (a) content; (b) pollution index](image)

(2) Total N
The content of total N is related to organic matter, thus the maximum average value also appears in Reach B, which can achieve 3562 mg/kg (Figure 5(a)). Based on the background value of 800 mg/kg, the pollution index can be obtained according to [14], as shown in Figure 5(b). If the index=1.50 is the criteria for judging whether sediment is polluted, layers I~III of Reach B and layers I, II of Reach A and Reach C are polluted, of which the pollution levels are greater than ‘medium’. Therefore, the average pollution depth is 2.0 m for Reach A, 3.0 m for Reach B and 2.0 m for Reach C.

(3) Total P
For total P, the maximum average value is detected in Reach B with 2862 mg/kg (Figure 6(a)). Based on background value of 600 mg/kg [15], the pollution index of total P can be calculated, as shown in Figure 6(b). Similarly, layers I~III (Reach B) and layers I~II (Reach A and Reach C) are polluted seriously, of which the pollution levels are greater than ‘medium’. The average pollution depth is 2.0 m for Reach A, 3.0 m for Reach B and Reach C.

3.2. Pollution assessment of toxic substances
These substances pose a serious threat to human health and the safety of ecological environment. For there are many electronic device manufacturers around the MZ River, the toxic substances are mainly to refer to Rohs2.0 revised directive, including phthalate and heavy metal elements.
(1) Phthalate

Phthalate detected in this paper includes DEHP, DNOP, BBP, DBP, DEP and DMP. The average concentration of phthalate were 38.56~49.71 μg/kg, 575.1~817.1 μg/kg, 262.3~576.7 μg/kg for Reach A, Reach B and Reach C respectively. Then, eleven points are chosen to reveal the distribution of phthalate, as shown in Figure 7. For Reaches A–C, concentration of layer I and layer II contribute about 90% to the total concentration, which means that toxic substances will be easily taken by aquatic organisms. What's worse, it will threaten human health. Reach B suffers the most serious pollution, of which the maximum concentration appears to be greater than 1000 μg/kg.

According to MalIszewska evaluation system [16], only the average phthalate concentration of layer I of Reach B belongs to ‘medium’. Besides, some points belongs to ‘severe’ for Reach B as discussed above. Generally, the average pollution depth is 1.0 m for Reach B, as shown in Figure 8.

(2) Heavy metal elements

Heavy metal elements like Hg, Pb, Cd and Cr are also toxic substances listed in Rohs2.0 revised directive. Concentrations of Pb, Cd and Cr are analysed in sediment. The results show that the average concentration of layer I, II and III can exceed ‘strong’ based on potential ecological risk index, which has been investigated in detail in [17]. The average pollution depth is 1.0 m for Reach A, 3.0 m for Reach B and Reach C.

3.3. Comprehensive pollution depths

As discussed above, different pollution categories give different pollution depths. Therefore, the average pollution depths should be determined by comprehensive pollution analysis, as shown in Table 1.

4. Conclusion

In the present study, the comprehensive pollution analysis of organic nutrients and toxic substances among sediment have been discussed. From the previous investigation, the following conclusions can be concluded.
The organic nutrients and toxic substances content decreases with increase of depth from surface to bottom (from layer I to layer IV) for Reaches A–C. The first layer appears to be polluted seriously, of which the pollution level can be ‘severe’ and threaten the water ecosystem.

According to the comprehensive pollution analysis, the pollution depths for different zones can be determined. The average pollution depths are 2.0 m for Reach A, 3.0 m for Reach B and Reach C in the present study.

Table 1. Comprehensive pollution depths for different reaches

| Category              | Reach A | Depth (m) | Reach B | Depth (m) | Reach C | Depth (m) |
|-----------------------|---------|-----------|---------|-----------|---------|-----------|
| Organic nutrients     | Organic matter | 0       | 2.0     | 1.0       |
|                       | Total N  | 2.0       | 3.0     | 2.0       |
|                       | Total P  | 2.0       | 3.0     | 3.0       |
| Toxic substances      | Phthalate | 0       | 1.0     | 1.0       |
|                       | Heavy metal elements | 1.0   | 3.0     | 3.0       |
| **Comprehensive pollution depths** |          | **2.0**  | **3.0** | **3.0**   |

Acknowledgement
This study is supported by Zhejiang Key Research and Development Program (2018C03G3241167); besides, it is also supported by Comprehensive Harnessing of Ecological Corridors (KY2018-SHJ-04) and wandering river regulation of Niyang River (KY2019-SHJ-05) from Power China Huadong Engineering Corporation Limited and the Natural Science Foundation of Zhejiang Province (LQ20E090006).
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