

Pollution and ecological risk assessment of heavy metal of urban river sediment in Suzhou city

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Abstract. Based on the measurement of 12 sediment samples from the Tuohe River of Suzhou City, Anhui Province, the heavy metal concentration of Cr, Cu, Zn, As, Pb and Ni were analyzed. Using the method of geoaccumulation index and potential ecological risk index, this paper evaluated heavy metal pollution characteristic of river sediment in Suzhou City. The result showed that: 1) most heavy metals concentrations were higher than soil background value of Anhui province, especially Cu and Zn, higher 5.19 times and 6.69 times than the background value, respectively, which pollution order was $Zn > Cu > Pb > As > Ni > Cr$. 2) among 6 heavy metal, the Igeo displayed Cu and Zn were the main pollution elements that the pollution was more serious; Cr is no pollution; As, Pb and Ni belonged to no pollution to light pollution. 3) all potential ecological risks index were less than 150 indicated the sediments were of low risk. For individual potential ecological risk index, their pollution order was: $Cu > Pb > As > Zn > Ni > Cr$. Cu and Pb had greater contribution rate to the potential ecological risk of sediment.

1. Introduction

River in the city is an important part of urban water bodies, and it is also one of the important factors of urban ecological system. With the development of urbanization and industrialization and the coming of the automobile, water environment pollution problems also is coming in the city river. At the same time, water body is affected by the pollutants along the river because of relatively closed river environment, poor self-purification to pollutants and low renovation speed [1]. Some studies have shown that water quality in the river flowing through city of our country is suffered varying degrees of contamination [2], in particular, the heavy metal pollution in river sediment is more serious [3]. Sediment is an important part of urban water ecosystem, which is not only the "source" and "sink" of water pollutants, but also the main living space and food sources of the benthic organisms [4, 5]. The heavy metal pollutants can be absorbed and accumulated by the benthic organisms, and transferred into the high trophic level organisms with the food chain, thereby affect the human health [6]. Therefore, the problem of heavy metal pollution has been one of the hot issues in the field of environmental science, and has achieved great achievements. For example: YANG Yi et al. studied the content, morphological characteristics of heavy metal in sediment and environmental quality of urban water body in Haikou City[7]; Pollution of heavy metal in sediment and river dredging in Hangzhou city were researched by Ding Tao et al. [8]; The potential risk of heavy metal in Puyang river basin were compared before and after dredging by Zhang Wei et al. [9]; XU Yongze studied the potential ecological risk and pollution characteristics of heavy metals of sediment in the Xiangjiang River [10]. From these documents we can see they mainly aimed at the sediments heavy metal pollution in the big city and the river basin, however, there are few studies on the sediments in some small or middle-sized cities such as Suzhou City, etc. Based on this, this paper used the methods of



geoaccumulation index and potential ecological risk index to evaluate heavy metal pollution through collecting samples of heavy metals in river sediments from different functional areas in Tuohe River in Suzhou City, which aimed to reflect the heavy metals pollution degree in Tuohe river and as a place to relax ecological impacted on human health.

2. Materials and Methods

2.1. Study Area

Suzhou City is located in the North of Anhui Province. Its longitude lies between $116^{\circ}09'$ and $118^{\circ}38'$ degrees east, and its latitude is between $33^{\circ}18'$ and $34^{\circ}38'$ degrees north. It is bordered by Suqian City to the east, Huaibei City, Shangqiu City and Heze City to the north, Bozhou City to the west, and Bengbu City to the south. The total area of Suzhou City is 9787 km^2 , whose Government governs one district and 4 counties, and the total population is 649.51 million at the end of 2015. Plain is the main terrain in Suzhou City, accounting for 91% of the land area, which has more developed agricultural production. Suzhou City is rich in coal reserves that coal mining plays an important role for Anhui province and even Chinese energy supply. The city river that mainly refers to the part of moat of Suzhou City is a tributary of the Tuohe River, whose whole river water depth is less than 2 meters and the annual average flow of about $5\sim 60 \text{ m}^3/\text{s}$, and is an important part of the Tuo River landscape zone in Suzhou City.

2.2. Sample Collecting and Processing

According to distribution of main functional zones, a total of 12 sediment samples were collected in April 2011 before the rainy season, and the site coordinates were noted with Hand-held GPS (Figure 1). Sediment samples were collected from outer surface, i.e. 5~20 cm. The samples were packed into polyethylene bags and took back laboratory, then air-dried at room temperature, impurities i.e. rocks, weeds and so on eliminated in samples, and after grinding through a 200 mesh sieve to use, finally, weighing each soil sample 4g to press by 30t pressure and determined the contents of Cr, Cu, Zn, As, Ni and Pb in the sediment with X-Ray fluorescence spectrometer (XRF), there is no determination of Hg because of accuracy problems. In order to ensure the accuracy, each of 3 samples will be calibrated with national standard sediment sample (GB W07307) and the relative standard derivation was less than 10%.

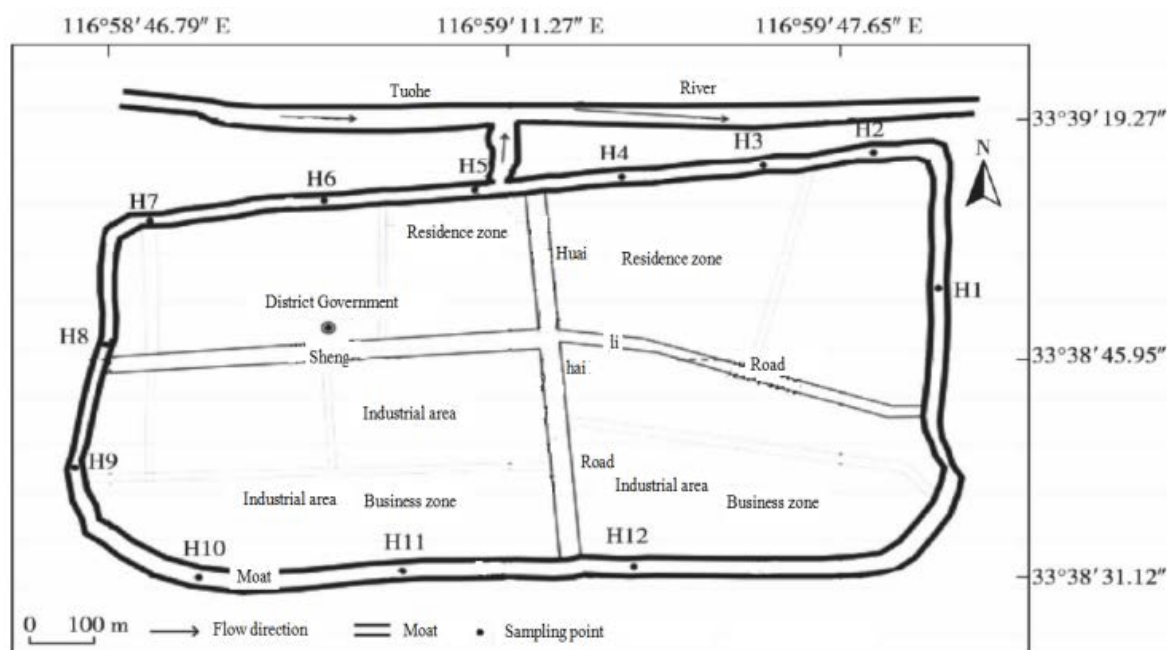


Figure 1. Geographical location and sampling point distribution in the study area

2.3. Methods

There are several models having been put forward to evaluate heavy metal pollution in soil. We used geoaccumulation index and potential ecological index in this paper.

The method of index of geoaccumulation is a quantitative target for research heavy metal pollution in the sediments of water environment [11]. Its calculation steps are as follows:

$$I_{\text{geo}} = \log_2 [C_n / (K B_n)] \quad (1)$$

In which, C_n is the measured values of heavy metals in sediment; B_n is geochemical background values of heavy metals, where this article take Soil background values in Anhui Province; K is coefficient because local rocks difference maybe lead to the background value changing (average value is 1.5), I_{geo} represents the index of geoaccumulation that reflects the enrichment degree of heavy metals in the sediment, according to the existing research it was divided into 7 grades ($I_{\text{geo}} < 0$, no pollution; $0 \sim 1$, no pollution to light pollution; $1 \sim 2$, moderate pollution; $2 \sim 3$, moderate pollution to strength pollution; $3 \sim 4$ strength pollution; $4 \sim 5$, strength pollution to extreme strong pollution; > 5 , extreme strong pollution).

The method of potential ecological risk index [12], also known as Hakanson index, calculate the degree of ecological harm of heavy metals pollution. Formula is as follows:

$$RI = \sum_{i=1}^m E_r^i = \sum_{i=1}^m T_r^i \cdot C_p^i = \sum_{i=1}^m T_r^i \cdot (C_s^i / C_n^i) \quad (2)$$

Where C_s^i is the measured values of the i th heavy metal in sediment; C_n^i is the geochemical background values of the i th heavy metal, which usually put to use the regional soil environment background value, we adopted the environmental geochemical baseline values of heavy metals in this paper; C_p^i is pollution coefficient of the i th heavy metal with respect to the reference value; T_r^i is toxicity response coefficient of the i th heavy metal that reflect their level of toxicity and how sensitive each species to pollution. (Cr: 2; Cu:5; Zn:1; As: 10; Ni:5; Pb:5). E_i is potential ecological harm index of the i th heavy metal, which shows the pollution degree of heavy metals and can be roughly divided into 5 grades (table 1); RI is comprehensive ecological risk index that can be roughly divided into 4 grades (table 1).

In this paper, all data analysis and mapping have been done by the Excel and SPSS17.0.

Table 1. Hazardous levels depending on potential ecological risk coefficient and potential ecological risk index

harmful degree	light	medium	strong	very strong	extremely strong
E_i	$E_i < 40$	$40 \leq E_i < 80$	$80 \leq E_i < 160$	$160 \leq E_i < 320$	$E_i \geq 320$
RI	$RI < 150$	$150 \leq RI < 300$	$300 \leq RI < 600$	$RI \geq 600$	

3. Result and Analysis

3.1. Descriptive Statistics

From table 2 we can see the average values of Cr, Cu, Zn, As, Pb and Ni were 73.08, 105.83, 414.83, 15.67, 54.67 and 47.50 respectively, all more than background values, which showed river sediment was affected by human activities, especially Cu and Zn, higher than the background value of 5.19 times and 6.69 times. The pollution order was as follows: $Zn > Cu > Pb > As > Ni > Cr$. The range of heavy metals contents of Zn and Ni was bigger from 54 to 1040 and from 10 to 108, with the coefficient of variation, 61.10% and 64.54%, respectively, which illustrated the heavy metals had more spatial difference. However, there is a smaller spatial difference for other heavy metals, Cr with smaller coefficient of variation under 20%.

Table 2. Statistic value of heavy metal of sediment in Suzhou City

	Min	Max	Average	background values	S.D.	Cv
Cr	54	102	73.08	62.6	14.28	19.54%
Cu	41	173	105.83	20.4	35.99	34.00%
Zn	54	1040	414.83	62	253.48	61.10%
As	8	23	15.67	9	4.66	29.73%
Pb	27	74	54.67	26.2	13.36	24.44%
Ni	10	108	47.50	29.8	30.66	64.54%

3.2. Analysis of Geoaccumulation Index

Using formula (1) the geoaccumulation index were calculated the results showed such as table 3. Table 3 made clear that the Igeo of Cr in all samples were less than 0, belonging to the non-pollution; Ni of samples were from no pollution to light pollution at H4, H5, H8 and H10, others no pollution; at sampling point H4, the heavy metal Cu was no pollution, belonged to no pollution to light pollution at H2, H6, H8, H11 and H12, the rest was moderate pollution; and the Igeo of Zn was less than 0 at H4, between 0 and 1 at H2, H5, H8, between 1 and 2 at H1, H6, H9, H11, H12, between 2 and 3 at H7, H10, belonging to no pollution, no pollution to light pollution, moderate pollution, moderate pollution to strength pollution, respectively; except H7 for no pollution to light pollution, As in other sampling points were no pollution; the heavy metal of Pb belonged to no pollution at H2, H4, H6, H8 and H11, others for no pollution to light pollution. From above, we can see the Igeo displayed Cu and Zn were the main pollution elements that the pollution was more serious; Cr is no pollution; As, Pb and Ni belonged to no pollution to light pollution.

Table 3. Geoaccumulation index (geo) of heavy metal in sediments

	Cr	Ni	Cu	Zn	As	Pb
H1	-1.08	-2.32	1.63	1.77	-0.32	0.50
H2	-0.95	0.00	0.50	0.04	-1.17	-0.25
H3	-1.17	-2.58	1.72	1.51	-0.03	0.35
H4	-0.40	0.85	-0.36	-1.47	-1.49	-0.96
H5	-0.79	0.14	1.11	0.95	-1.03	0.24
H6	-1.32	-1.74	0.93	1.29	-0.32	-0.16
H7	-0.89	-0.05	1.22	2.79	0.03	0.19
H8	-0.70	0.26	0.68	0.65	-0.91	-0.43
H9	-0.97	0.00	1.04	1.79	-0.32	0.29
H10	-0.52	0.09	1.05	2.03	-0.58	0.24
H11	-0.93	-2.10	0.79	1.56	-0.40	-0.04
H12	-1.19	-1.10	0.81	1.13	-0.49	0.17

3.3. Potential Risks Evaluation and Analysis

Potential risks evaluation was carried out in this paper by the method of Hakanson index (potential ecological risks index). The index of potential ecological risks enables the assessment of threaten to environment or human health. With the help of formula (2), the results of Ei and RI of Cr, Cu, Zn, As, Ni and Pb are listed in table 4. From table 4, the mean of potential ecological risk index was 83.45 and all indexes were less than 150 indicated the sediments were of low risk. For individual potential ecological risk index, their pollution order was: Cu > Pb > As > Zn > Ni > Cr. As we know, the greater the potential ecological risk index of an element, the greater contribution rate to the potential ecological risk of the sediment. So, Cu and Pb had greater contribution rate to the potential ecological risk of sediment. Except Cu and Pb, the Ei values of all other heavy metal elements were far less than 40 that displayed their ecological harm belonged to slightly polluted. The Ei values of Cu at H1 and H3, Pb at H1 were more than 40, illustrating ecological risk was moderately polluted.

Table 4. Ecological harmful index(E_r^i)and risk assessment (RI)

	E_r^i						RI
	Cr	Ni	Cu	Zn	As	Pb	
H1	1.94	0.88	48.57	8.40	12.24	40.17	112.21
H2	2.12	4.41	22.05	2.54	6.80	23.89	61.81
H3	1.82	0.74	51.55	7.02	14.96	36.37	112.45
H4	3.09	7.94	12.22	0.89	5.44	14.66	44.24
H5	2.36	4.85	33.67	4.78	7.48	22.14	75.29
H6	1.64	1.32	29.80	6.06	12.24	25.52	76.57
H7	2.21	4.26	36.35	17.14	15.64	32.57	108.18
H8	2.52	5.29	25.03	3.87	8.16	21.17	66.04
H9	2.09	4.41	32.18	8.52	12.24	34.74	94.19
H10	2.85	4.71	32.48	10.12	10.20	33.66	94.01
H11	2.15	1.03	27.12	7.28	11.56	27.69	76.82
H12	1.79	2.06	27.41	5.41	10.88	32.03	79.57
mean	2.22	3.49	31.54	6.84	10.65	28.72	83.45

4. Conclusion

1) The average values of Cr, Cu, Zn, As, Pb and Ni that were 73.08, 105.83, 414.83, 15.67, 54.67 and 47.50, respectively, were all more than background values. To a certain extent, river sediment was affected by human activities, especially Cu and Zn, higher than the background value of 5.19 times and 6.69 times. The pollution order was as follows: Zn> Cu> Pb> As> Ni> Cr.

2) The geoaccumulation index made clear Cu and Zn were the main pollution elements that the pollution was more serious; Cr is no pollution; As, Pb and Ni belonged to no pollution to light pollution.

3) All potential ecological risks index were less than 150 indicated the sediments were of low risk. For individual potential ecological risk index, their pollution order was: Cu > Pb > As > Zn > Ni > Cr. Cu and Pb had greater contribution rate to the potential ecological risk of sediment.

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