

# Application of multivariate statistical approach to identify heavy metal sources in sediment and waters: a case study in Yangzhong, China

Jian Zhou · Dongsheng Ma · Jiayong Pan · Wenming Nie · Kai Wu

Received: 9 April 2007 / Accepted: 21 May 2007 / Published online: 28 June 2007  
© Springer-Verlag 2007

**Abstract** Multivariate statistical approach is used to identify the sources of heavy metals (Bi, Cd, Co, Cr, Mn, Pb, U, V, and Zn) in surface water and freshly deposited riverine sediment samples in Yangzhong city, China. The metal concentration data for the water and sediment samples are reported in terms of basic statistical parameters and metal-to-metal correlations. In both surface water and sediment samples, significant correlations are observed between some metals. Principal component analysis and cluster analysis distinguishes factors of lithogenic and anthropogenic origin. Bismuth, Cd, Co, and Pb (Co only for water samples) contents are controlled by the regional lithogenic high background factor; Co, Mn, U, and V (Co only for sediment samples) are interpreted to be mainly inherited from soil parent materials, while Cr, Zn, and Mn in the two kinds of samples are recognized as the tracer of industrial pollution. Obvious similarity between factor loadings of the two kinds of samples is observed, evidencing that metal variability in the two kinds of samples is controlled by the same sources. Statistical analysis agrees with discussion based on background value and field

survey of point-source pollutant affected sediment, making this statistical discussion more convincing.

## Introduction

In the past few decades, heavy metals accumulation in environment have been attracting more and more attention of researchers and community because of their toxicity, persistence in the environment and subsequent accumulation in aquatic habitats (Facchinelli et al. 2001; Loska and Wiechula 2003; Upadhyay et al. 2006). The Yangtze Delta located in the lower reaches of the Yangtze River (Changjiang) is one of the fastest developing regions of China in economy and society. Industrialization progress and urban sprawl causes heavy metal accumulation in environmental of this region (Liao et al. 2004, 2005; Wan et al. 2006; Wang et al. 2005a). Regional Cd geochemical anomalies have been discovered during the multi-target geochemical survey of the Changjiang drainage area in recent years (Ma et al. 2004). This anomaly of Cd concentration in soil and sediment which spreads along with Changjiang water system is a potential threat to local community.

Heavy metals in environment mostly come from lithogenic and anthropogenic sources. Chemical leaching of bedrocks, water drainage basins and runoff from banks are the primary sources for the lithogenic contribution of heavy metals. Discharge of urban and industrial waste water, combustion of fossil fuels, mining and smelting operations, processing and manufacturing industries, waste disposal including dumping, etc., are primary anthropogenic sources of pollution (Klavins et al. 2000; Pardo et al. 1990; Yu et al. 2001). In the last decades, the natural input of several heavy metals to soils due to pedogenesis has been exceeded by the

---

J. Zhou · D. Ma (✉) · W. Nie · K. Wu  
State Key Laboratory for Mineral Deposit Research,  
Nanjing University, Nanjing 210093,  
People's Republic of China  
e-mail: dongisma@public1.ptt.js.cn

J. Zhou · D. Ma · W. Nie · K. Wu  
Department of Earth Sciences, Nanjing University,  
Nanjing 210093, People's Republic of China

J. Pan  
Department of Geoscience and Resource Information,  
East China Institute of Technology, Fu Zhou 344000,  
People's Republic of China

human input, even on a regional scale (Facchinelli et al. 2001). It is also important to apportion the different source of heavy metals in environment as well as determine their total concentration. Methods commonly used for distinguishing between anthropogenic and geogenic sources of the potential toxic elements include element speciation, profile distribution, and spatial distribution, but they are not sufficiently reliable to distinguish between sources of element concentration on their own and should be associated with additional information such as parent rock composition or known anthropogenic loads (Boruvka et al. 2005).

Multivariable statistic analysis provides an alternative method to identify pollution sources, to apportion natural versus anthropogenic contribution and to give indications about transport processes and environmental conditions. Principal component (PC) analysis (PCA) and derivative methods have been widely used in geochemical applications to reach the objective (Boruvka et al. 2005; Facchinelli et al. 2001; Filgueiras et al. 2004; Manta et al. 2002; Qu and Kelderman 2001; Wang et al. 2005a; Yu et al. 2000). Clustering analysis (CA) is often coupled to PCA to check results and provide grouping of individual parameters and variables (Facchinelli et al. 2001; Tariq et al. 2006; Wang et al. 2005a). Conjunction with CA, PCA provides a means for ensuring proper source identification for a given metal distribution pattern in water and sediment (Everitt 1993; Jolliffe 1986; Upadhyay et al. 2006).

The city of Yangzhong is composed of four alluvions of Yangtze River, which were formed by deposition of the river sediments before the fifteenth century. Yangzhong is an industry city, which is developing quickly since the 1970s and is now famous for its engineering electric appliance, galvanization, and chemical production. The record of riverine deposition processes and anthropogenic factors are both available in this region, making Yangzhong an ideal location for this study. The present study is carried out as a preliminary survey on Yangzhong City water and top sediments contamination. The main objectives of this study are: (1) determine the average level and distribution of some heavy metals (Bi, Cd, Co, Cr, Mn, Pb, U, V, Zn) both in water and top sediments in the city; (2) to define their natural or anthropogenic source; (3) to identify their local or exotic source to cause contamination in top sediment or/and water.

## Materials and methods

### Study area

The city of Yangzhong is located in the southern part of Jiangsu Province (China), the geographic position between 32°00' and 32°19'N, 119°42' and 119°56'E (Fig. 1). The



**Fig. 1** Sketch map of study area and sampling sites in Yangzhong City

city has a total area of 332 km<sup>2</sup>, including 228 km<sup>2</sup> terrene area, made up of four blocks of alluvion. The biggest one of them, the “Taiping alluvion”, is the second largest alluvion in the Yangtze River. There are 14 artificial rivers inside Taiping alluvion, with approximately 84.2 km of total length.

Yangzhong city with about 278,000 inhabitants is a rising industrial city, which produces one fifth of the nation’s engineering electric appliance every year and so is named “the island of engineering electric appliance”. Minitype factories for galvanization are also popular in this city. Although there is a decreasing trend of incidence rate between 1991 and 2003, Yangzhong city belongs to a high-incidence area of stomach cancer and esophageal cancer (Wang et al. 2005b). It is believed that the high incidence rate of these cancers is probably correlated to environmental problems (Cai 1993).

### Sampling

Total 19 top sediment samples (1–5 cm deep top layer) from Yangzhong water system (Fig. 1), including inside river and Yangtze River, were collected manually with a stainless steel spatula, cleaned manually for foreign matter and carried within zip-mouthed PVC packages. In order to reduce the possibility of random influence of urban waste, three sub-samples, with a 10 × 10 cm surface, were taken at each sampling point and then mixed to obtain a bulk sample. Total 28 surface layer (0–10 cm) water samples

collected at the same site with the sediment sampling were filtered under pressure through 0.46 µm filter instantly, subsequently acidified to pH < 1 and carried cool and dark in airproof bottles. Water and sediment samples were collected at the same position for most sampling sites, while certain of the sediment samples are not available at that position. Additionally, to examine the impact from industrial waste water, three sediment samples from the end of one effluent drain directly connected to a minitype factory for galvanization were taken.

**Experimental**

Sediment samples were air-dried and powdered within an agate mortar. The powdered sample is heated again in drying oven (90°C) for 12 h before been weighted. Fifty milligram powdered samples were digested with 1 ml HF and 0.6 ml HNO<sub>3</sub> mixed acids in a tightly sealed Teflon PFA screw-cap beaker, heated for 96 h on a hot plate at 190°C. Then the samples were evaporated nearly to dryness and were dissolved again with 1.0 ml HNO<sub>3</sub> by heating for 3–5 h at 140°C. For organic carbon-enriched samples, the residual samples were repeatedly dissolved in 1.6 ml HNO<sub>3</sub> at 140°C until all organic carbon was dissolved. One milliliter Rh solution (500 µg/L) was added to the sample solution as internal standard, and then the total sample solutions were diluted by 1:1000 in mass. Concentrations of trace elements (Bi, Cd, Co, Cr, Mn, Pb, U, V, and Zn) of sediment and water samples were determined using High Resolution Inductively Coupled Plasma Mass Spectrometry (Finnigan Element II) in the State Key Laboratory for Mineral Deposits Research, Nanjing University. The reagents used were all of spectroscopic grade. Measures of standard reference material (SDO-1, provided by USGS), reagent blanks and three duplicated samples randomly selected from the set of available samples were

used to assess contamination and precision. Analytical precision for concentrations of trace elements, measured as relative standard deviation, is better than 5%. Recovery in this study is better than 95%.

**Statistical analysis**

Multivariate data analysis techniques can be used to assess the complex eco-toxicological processes by showing the relationship and interdependency among the variables and their relative weights (Bartolomeo et al. 2004). PCA is a multivariate method mainly used for data reduction. It aims at finding a few components that explain the major variation within the data (Danielsson et al. 1999). Each component is a weighted, linear combination of the original variables. A PC analysis is performed on the correlation or covariance matrix between the variables (in this study variables are concentrations of elements in sediment/water samples), followed by varimax rotation in order to make the components more interpretable (Jolliffe 1986). Cluster analysis can be used to grouping objects of similar kind. STATISTICA software was used to conduct the relevant statistical analysis of the data (StatSoft, 1999). In our PCA, factors who represents more than 85% of the total variation are chosen (Facchinelli et al. 2001).

**Results and discussion**

**Descriptive statistics**

For both water and sediment samples collected, complete statistical summary of the distribution parameters is given in Table 1. Based on mean values, the metals follow the decreasing concentration order: Mn > Zn > V > Cr > Pb > Co > U > Bi > Cd (Table 1). The data show that Mn

**Table 1** Statistical summary of selected metal concentrations in sediment and water samples in Yangzhong water system

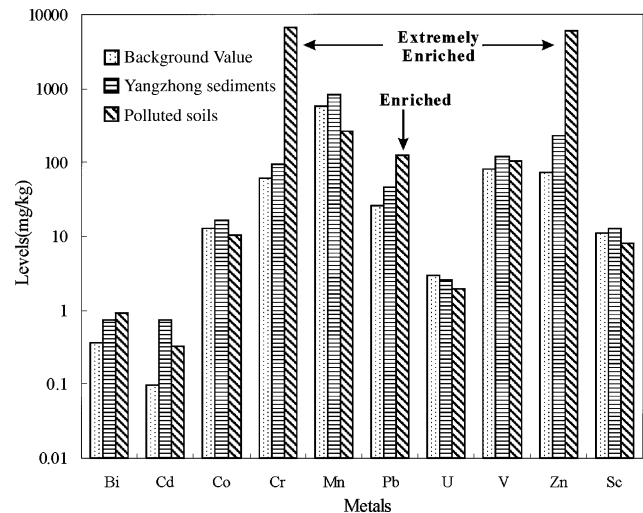
Metals	Sediment (mg/kg, n=19)					Water (µg/L, n=28)				
	Mean	Min	Max	SD	Skewness	Mean	Min	Max	SD	Skewness
Bi	0.755	0.314	1.327	0.306	0.089	0.043	0.001	0.963	0.180	5.277
Cd	0.749	0.279	1.459	0.370	0.173	0.117	0.004	1.061	0.206	3.871
Co	16.376	11.502	21.509	2.802	0.141	0.319	0.001	3.581	0.666	4.672
Cr	94.522	68.704	139.52	19.316	0.780	6.414	1.938	28.164	6.932	2.349
Mn	817.76	539.76	1102.1	156.67	-0.185	82.634	2.354	385.29	98.032	1.798
Pb	46.248	23.944	67.210	15.078	-0.050	2.585	0.472	15.839	2.817	4.185
U	2.568	1.771	3.002	0.366	-0.858	0.789	0.018	1.472	0.297	-0.457
V	122.16	90.783	155.25	19.132	-0.131	2.786	0.925	5.865	1.300	1.033
Zn	226.90	66.09	1457.0	321.07	3.559	114.61	30.84	572.92	124.18	2.606
Sc	12.672	9.711	16.483	1.917	0.089	n.a.	n.a.	n.a.	n.a.	n.a.

n.a. means not available

and Zn are among the dominant metals in the top sediment samples. Vanadium, Cr and Pb have lower concentrations than Mn and Zn. Cobalt and U also have a substantial level while Bi and Cd show the minimum mean concentration in the top sediment samples. Especially, the concentration of Zn shows extremely high standard deviation and positive skewness evidencing a strong skewness factor for this metal. The reason for this strong skewness is explained by two sediment samples (sample #144 and #122) containing 1457 and 617 mg/kg of Zn, respectively.

In the case of water samples, the metal concentration distribution pattern follows the decreasing order: Zn > Mn > Cr > V > Pb > U > Co > Cd > Bi (Table 1). Zinc and Mn are the most dominant element of these metals in the water. Chromium, V and Pb have a lower concentration. The water samples are found to have a lowest level for Cd and Bi, while the level of U and Co were slightly above them. Trace metals concentrations in water samples show much higher skewness than in top sediment samples, indicating that metal concentrations were not normally like occurred in the sediments. This observation could be explained by that metals dissolved in water is more active and easier to be transported than in sediments, so that their content in water are more sensitive to the skewness factors, like foreign input or the change in physico-chemical conditions, than in sediment.

Table 2 compares the metal levels of Yangzhong sediment, water and polluted sediment samples to background levels. In Yangzhong top sediment samples, the arithmetic mean concentration for Cd, Pb, Bi, and Zn are much higher than the background value, which is arithmetic mean values of metals in natural soils of China (Chinese General Station of Environmental Monitoring 1990). The concentration of Cr, V, Co, Mn is nearly the same with background value (Table 2; Fig. 2), showing that these metals in top sediments of Yangzhong water system were not



**Fig. 2** Comparison of metal levels of background values, mean metal concentration in Yangzhong sediment samples and 3 polluted samples taken from the end of the galvanisation factory effluents. In the polluted samples, Cr, Pb, and Zn are enriched

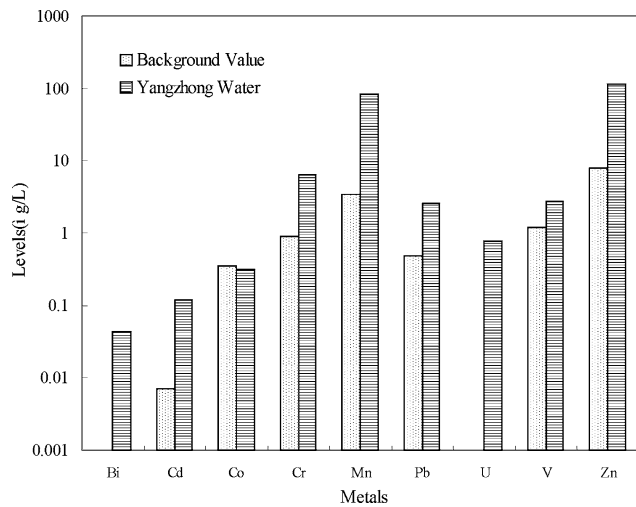
substantially influenced by anthropogenic factors in regional scale. Compared to background value, metal levels in natural waters from the main stream of Yangtze river (Wu et al. 1990), Mn, Zn, Cd, Cu, Cr, and Pb concentrations are much more higher in Yangzhong water samples, while the level of Co is slightly lower (Table 2; Fig. 3).

The three polluted sediment taken from the end of effluent drains were determined and the results were given in Table 2 and Fig. 2. Chromium and Zn were extremely enriched in the three samples, with mean concentration of 6659.435 mg/kg for Cr and 6097.503 mg/kg for Zn (Table 2). This indicates that the effluent discharged from the minitype galvanization factory impose great quantities of these two metals to nearby environment, causing distinct enrichment in sediments for Cr and Zn. Pb is also enriched

**Table 2** Mean metal concentration of sediment, water and polluted sediment samples in Yangzhong versus background level

Metals	Sediment (mg/kg)			Water ( $\mu\text{g/L}$ )	
	Background	YZ	Polluted	Background	YZ
Bi	0.37	0.755	0.907	n.a.	0.043
Cd	0.097	0.749	0.330	0.007	0.117
Co	12.7	16.376	10.195	0.35	0.319
Cr	61	94.522	6659.435	0.889	6.414
Mn	583	817.764	264.747	3.4	82.634
Pb	26	46.248	125.397	0.485	2.585
U	3.03	2.568	1.952	n.a.	0.789
V	82.4	122.165	103.758	1.22	2.786
Zn	74.2	226.902	6097.503	7.95	114.61
Sc	11.1	12.672	8.026	n.a.	n.a.

n.a. means not available. YZ = Yangzhong



**Fig. 3** Comparison of metal levels of background values and mean metal concentration in Yangzhong water samples

in the polluted sediment samples. The concentrations of Bi, Cd, Co, Mn, U, and V in the polluted sediments were around the background value and mean concentration of Yangzhong sediments, showing that these elements were not impacted by the effluent from this factory (Fig. 2).

Inter-element relationships and hierarchical cluster analysis

Inter-element relationships can provide interesting information on element sources and pathways (Manta et al. 2002). The metal correlations in the samples are listed in Tables 3 and 4. The relevant data for top sediments show significant correlations between Bi and Cd as well as Bi and Pb. This indicates that Bi in sediments samples has a strong association with Cd and Pb statistically, and it may shares a common origin with them. Other positively correlated relationships, such as those in Co–U, Co–Pb, Co–V and V–Pb–U may also be seen. On the other hand, Cd does not show strong correlation with Cr as well as Zn, indicating that their distributions

were not controlled by same factor. Zinc is not strongly associated with other elements in top sediment samples. Scandium is a conservative (very insoluble) element hosted in a variety of ferromagnesian minerals, and is considered to represent the lithogenic source in surface environment (Audry et al. 2004). Table 3 shows the inter-element relationships between the nine researched elements and Sc. The strong correlation between Sc and elements (e.g. Co, U, V, and Mn) represents that these elements have a more lithogenic origin. Meanwhile, the low correlation coefficient of Sc–Cr and Sc–Zn shows that concentrations of Cr and Zn are dominated by anthropogenic factors. The results of the correlation study, therefore, evidence mutual metal dependence in sediments as well as existence of a stronger correlation within certain group of trace metals.

In the water samples, distinct correlations are only observed between every two metal pairs among Bi, Cd, Co, and Pb ( $r > 0.9, P < 0.01$ ), while other five elements do not show obvious relativity between each other. This resembles case of the sediment samples.

Three clusters are observed from the dendrograms (Figs. 4, 5) for the metals in top sediment and water samples with significant linkage distance, indicating relatively high independency for each cluster. For top sediment samples, Bi and Cd, very well correlated with each other, form a cluster with Pb. The association of Co and V is shown in Fig. 3, which form another cluster together with U. Zinc is isolated and joined to the Cr–Mn cluster only very late. In so far as water samples, Bi and Co that correlates very well with each other are associated with Pb. Bismuth, Co, Pb, and Cd form the first cluster, Cr, and Mn associated as the second cluster and Mn, V, and U form the third cluster.

Principal component analysis

To quantitatively evaluate the clustering behavior, PC analysis with varimax normalization (PCA-V) is applied, and the results are given in Table 5 for the water and

**Table 3** Linear correlation coefficient matrix\* for selected metals in sediment samples ( $n = 19$ )

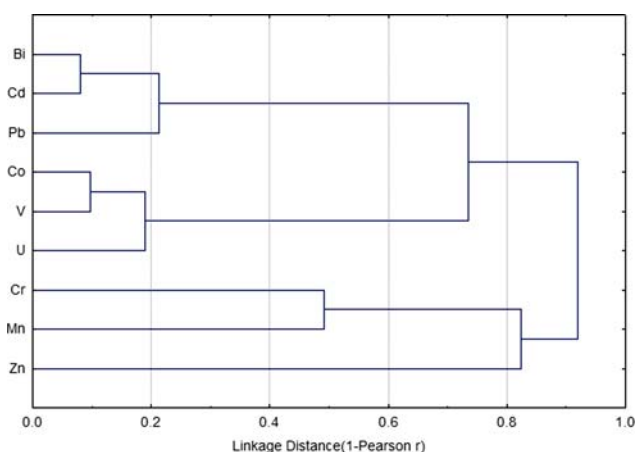
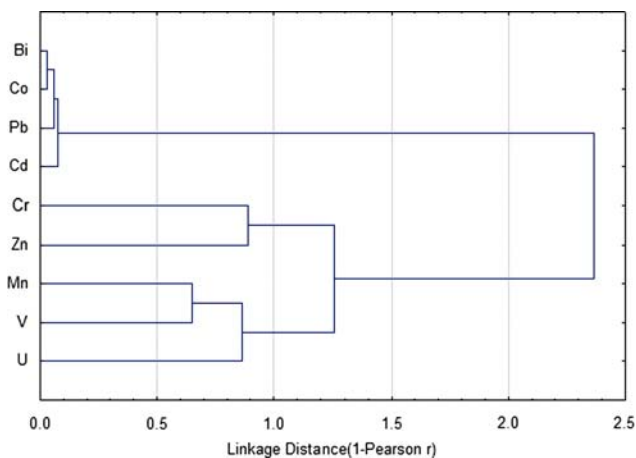
	Bi	Cd	Co	Cr	Mn	Pb	U	V	Zn
Bi	1.00								
Cd	<b>0.92</b>	1.00							
Co	<b>0.70</b>	0.53	1.00						
Cr	0.32	0.20	0.40	1.00					
Mn	0.43	0.33	<b>0.75</b>	0.51	1.00				
Pb	<b>0.87</b>	<b>0.77</b>	<b>0.81</b>	0.55	<b>0.68</b>	1.00			
U	<b>0.71</b>	0.55	<b>0.77</b>	0.40	0.44	<b>0.66</b>	1.00		
V	<b>0.68</b>	0.55	<b>0.90</b>	0.45	<b>0.68</b>	<b>0.73</b>	<b>0.90</b>	1.00	
Zn	0.45	0.21	0.46	0.34	0.18	0.49	0.37	0.34	1.00
Sc	<b>0.64</b>	0.52	<b>0.90</b>	0.25	<b>0.60</b>	<b>0.67</b>	<b>0.89</b>	<b>0.96</b>	0.28

\* Correlations in bold are significant at  $P < 0.01$

**Table 4** Linear correlation coefficient matrix\* for selected metals in water samples ( $n = 28$ )

	Bi	Cd	Co	Cr	Mn	Pb	U	V	Zn
Bi	1.00								
Cd	<b>0.91</b>	1.00							
Co	<b>0.97</b>	<b>0.96</b>	1.00						
Cr	-0.10	-0.10	-0.08	1.00					
Mn	0.04	0.08	0.16	0.01	1.00				
Pb	<b>0.93</b>	<b>0.94</b>	<b>0.96</b>	-0.05	0.06	1.00			
U	0.14	0.26	0.23	-0.19	0.16	0.27	1.00		
V	-0.11	0.25	0.10	0.11	0.35	0.11	0.22	1.00	
Zn	0.12	0.05	0.12	0.11	0.29	0.05	-0.16	-0.04	1.00

\* Correlations in bold are significant at  $P < 0.01$

**Fig. 4** Dendrogram of selected metals in sediment samples using ward's method**Fig. 5** Dendrogram of selected metals in water samples using ward's method

sediment samples. Four factors originate with a cumulative variance of 91.92% for the top sediment samples. The overwhelming 62.47% of total variance is contributed by

PC 1, showing higher loadings for Bi, Cd, and Pb, evidencing the main metal contribution coming from the influence of widespread regional high Cadmium background anomaly (Cheng et al. 2005a). The high Cadmium background anomaly in sediment and soil is distributed along with the both riversides of the Yangtze River (Cheng et al. 2005a), verified as the result of natural precipitation processes of Cd in water system (Ma et al. 2004). The source of Cd could be from weathering of Cd-rich bedrocks accompanied by anthropogenic input at some local area (Cheng et al. 2005b), whereas the specific forming mechanism and ecological effect of this anomaly have not yet been carefully revealed (Ma et al. 2004). This factor could be identified as the “high background lithogenic factor”. PC 2 and PC 3 loaded by Cr, Mn, and Zn indicate the likely influence from local industrial effluent and these PCs could be considered to be dominated by the “local industrial factor”. The producing progress of engineering electric appliance and galvanization, accompanied by the drainage of untreated effluent like acid wash and plating liquid results in the tremendous enrichment of Zn and Cr in the polluted soils (Fig. 2), and could be the factor that control these two PCs. Zinc and Cr may be controlled by different industrial source. PC 4 with high contribution of Co, Mn, U, and V accounting for 7.48% of the total variance is controlled by the “natural factor” of the lithogenic process during weathering progress of natural parent materials such as rocks and soils. The mean concentration of the four elements in top sediment samples as well as the polluted soils were not substantially higher or ever a bit lower than the background value (Fig. 2), indicating that these metals were not influenced by anthropogenic factors. Mn emerges at both PC2 and PC 4, showing that this metal has a mixed source.

Four PC are separated for the water samples, with a cumulative variance of more than 85%. PC 1 exhibits high loading for Bi, Co, Cd, and Pb with a maximum contribution of 42.79% of total variance. It takes its origin from the

**Table 5** Factor loadings of selected metals in sediment samples and water samples

Metals	Sediment				Water			
	PC1	PC2	PC3	PC4	PC1	PC2	PC3	PC4
Bi	<b>0.86</b>	0.13	0.24	0.41	<b>0.98</b>	-0.13	-0.07	0.07
Cd	<b>0.96</b>	0.06	0.01	0.25	<b>0.96</b>	0.18	0.02	0.04
Co	0.33	0.3	0.19	<b>0.83</b>	<b>0.98</b>	0.09	-0.10	0.05
Cr	0.1	<b>0.88</b>	0.25	0.14	-0.04	0.12	-0.01	<b>-0.92</b>
Mn	0.15	<b>0.66</b>	-0.15	<b>0.6</b>	0.01	<b>0.58</b>	<b>-0.65</b>	0.11
Pb	<b>0.68</b>	0.47	0.23	0.45	<b>0.98</b>	0.09	0.02	0.03
U	0.36	0.07	0.23	<b>0.81</b>	0.20	<b>0.55</b>	0.22	0.49
V	0.32	0.25	0.11	<b>0.89</b>	0.04	<b>0.86</b>	0.01	-0.19
Zn	0.15	0.16	<b>0.93</b>	0.19	0.08	-0.14	<b>-0.88</b>	-0.11
Eigen value	5.62	1.09	0.88	0.67	3.85	1.49	1.26	1.16
Loading%	62.47	12.15	9.82	7.48	42.79	16.52	14.01	12.83
Cumulative%	62.47	74.62	84.44	91.92	42.79	59.32	73.33	86.17

Values of dominant elements in each factor is reported in bold

Extraction method: PCA, Rotation method: Varimax with Kaiser Normalization

influence of widespread regional high Cadmium background anomaly (Ma et al. 2004) as is discussed above for the sediment samples. PC 2 (16.52% of total variance), accounts for high contribution of V, U, and Mn, reflects the control of parent materials weathering progress. PC 3 brings forth the major contribution from Mn and Zn at 14.01% of total variance. PC 4 with a variance loading of 12.83% is dominated by the loading of Cr. PC 3 and PC 4 can be identified as the tracer of local industrial effluent. Mn emerges at both PC 2 and PC 3, showing that this metal has a mixed source as what is observed in the sediment.

The factor loading of top sediment is much the same with which for the water samples. The groupings for the nine elements in the two kinds of samples are almost the same while the ranking of PCs based on their contribution to the total variance is slightly different. The “natural factor” controls the PC 2 of water samples and PC 4 of top sediments. The “local industrial impacts” is represented by PC3 and PC 4 for water samples and PC 2 and PC 3 for sediment samples. The similarity in element cluster behavior between the two kinds of samples, which can also be observed in the cluster analysis (Figs. 4, 5), reveals that the metal variability in the two kinds of samples is controlled by the same sources.

Although many of the same control factors are observed in the water and sediment samples, their relative importance are different. For example, the “natural factor” stands as the second most important factor (PC 2) in water while in the fourth place for sediment. The “local industrial impacts factor” is a more significant controlling factor for sediment samples (PC 2 and PC 3) than for water samples (PC 3 and PC 4). This would be presumably due to the characteristic that heavy metals resulting from anthropogenic contami-

nation are either associated with organic matter present in the thin fraction of the sediments, or adsorbed on Fe/Mn hydrous oxides, or precipitated as hydroxide, sulphides and carbonates (Forstner 1985). Anthropogenic released metals (Cr and Zn) tend to reside in solid phase rather than dissolved phase in water-sediment interface. So it is more probably that water receives less influence from the anthropogenic impact than sediment samples.

**Conclusions**

Multivariable statistic approaches (PCA-V and CA) are used as a tool to distinguish sources of heavy metal elements in riverine sediment and water in Yangzhong city. Natural and anthropogenic input of heavy metals in the water and sediment samples is distinguished. Present research suggests that:

- (1) Distributions of Bi, Cd, Co, and Pb (Co only for water) both in water and sediment all are controlled by the “high background lithogenic factor”, that means, they are regional and affected by input from upstream areas;
- (2) Co, Mn, U, and V (Co only for sediment) representing “Natural factor” of the lithogenic process seems to be originated from parent material in sediment and water;
- (3) Cr, Zn, and Mn both in the water and sediment samples have a majority of contribution from the industrial extraction of waste water, which can be concluded as the “local industrial factor”;
- (4) The pattern of distribution for Mn is affected by a mixed source.

The result indicates that the element clustering behavior is similar between the water and sediment samples, revealing that the metal contents in the two kinds of samples are controlled by the same sources. However, the relative importance of each of the factors of the water and sediment samples is different. The result agrees with discussion based on the background value and field survey on point-source pollutant affected sediment samples. The results also reconfirmed that multivariable statistic method (principal component analysis and cluster analysis) of a small set of data together with other information can provide valuable insight in the context of the sources of soil pollutants (Boruvka et al. 2005).

## References

- Audry S, Schafer J, Blanc G, et al (2004) Fifty-year sedimentary record of heavy metal pollution (Cd, Zn, Cu, Pb) in the Lot River reservoirs (France). *Environmental Pollut* 132:413–426
- Bartolomeo AD, Poletti L, Sanchini G, et al (2004) Relationship among parameters of lake polluted sediments evaluated by multivariate statistical analysis. *Chemosphere* 15:1323–1329
- Boruvka L, Vacek O, Jehlicka J (2005) Principal component analysis as a tool to indicate the origin of potentially toxic elements in soils. *Geoderma* 128:289–300
- Cai D (1993) Environment quality of Yangzhong county of high cancer incidence. *Agro-Environ Prot* 12:127–130, 119 (in Chinese)
- Cheng H-X, Yang Z-F, Xi X-H, et al (2005a) A research framework for source tracking and quantitative assessment of the Cd anomalies along the Yangtze River Basin. *Earth Sci Front* 12:261–272 (in Chinese with English Abstract)
- Cheng H, Yang Z, Xi X, et al (2005b) Strategy and tactics for tracing and source tracking of Cd anomalies along the Changjiang River Basin. *Quaternary Sci* 25:285–291 (in Chinese with English Abstract)
- Chinese General Station of Environmental Monitoring (1990) The background values of elements in soils of China. China Environmental Science Press, Beijing (in Chinese)
- Danielsson Å, Cato I, Carman R, et al (1999) Spatial clustering of metals in the sediments of the Skagerrak/Kattegat. *Appl Geochem* 14:689–706
- Everitt BS (1993) Cluster analysis. Heineman, London
- Facchinelli A, Sacchi E, Mallen L (2001) Multivariate statistical and GIS-based approach to identify heavy metal sources in soils. *Environ Pollut* 114:313–324
- Filgueiras AV, Lavilla I, Bendicho C (2004) Evaluation of distribution, mobility and binding behaviour of heavy metals in surficial sediments of Louro River (Galicia, Spain) using chemometric analysis: a case study. *Sci Total Environ* 330:115–129
- Forstner U (1985) Chemical forms and reactivities of metals in sediments. In: Leschber R, Davis RD, L'Hermite P (eds) *Chemical methods for assessing bioavailable metals in sludge and soils*, Elsevier, London, pp 1–30
- Jolliffe IT (1986) *Principal component analysis*. Springer, New York
- Klavins M, Briede A, Rodinov V, et al (2000) Heavy metals in river of Latvia. *Sci Total Environ* 262:175–183
- Liao Q-L, Wu X-M, Weng Z-H, et al (2004) Basic results of multi-target geochemical survey in the Nanjing area and its relevant problems. *Geol China* 31:70–77 (in Chinese with English Abstract)
- Liao Q, Huang S, Fan D, et al (2005) Vertical distribution in lake sediments and soils and partition within paddy for relevant trace elements: preliminary testing results from eco-geochemical survey in Jiangsu. *Quaternary Sci* 25:331–339 (in Chinese with English Abstract)
- Loska K, Wiechula D (2003) Application of principal component analysis for the estimation of source of heavy metal contamination in surface sediments from the Rybnik Reservoir. *Chemosphere* 51:723–733
- Ma S, Zhu L, Wang Z (2004) Origin and ecological effect of regional Cd geochemical anomalies in plain areas. *Geol Bull China* 23:1083–1087 (in Chinese with English Abstract)
- Manta DS, Angelone M, Bellanca A, et al (2002) Heavy metals in urban soils: a case study from the city of Palermo (Sicily), Italy. *Sci Total Environ* 300:229–243
- Pardo R, Barrado E, Perez L, et al (1990) Determination and speciation of heavy metal in sediments of the Pisuerga river. *Water Res* 24:373–379
- Qu WC, Kelderman P (2001) Heavy metal contents in the Delft canal sediments and suspended solids of the River Rhine: multivariate analysis for source tracing. *Chemosphere* 45:919–925
- Tariq SR, Shah MH, Shaheen N, et al (2006) Multivariate analysis of trace metal levels in tannery effluents in relation to soil and water: a case study from Peshawar, Pakistan. *J Environ Manage* 79:20–29
- Upadhyay AK, Gupta KK, Sircar JK, et al (2006) Heavy metals in freshly deposited sediments of the river Subernarekha, India: an example of lithogenic and anthropogenic effects. *Environmental Geology* 50:397–403
- Wan H-Y, Zhou S-L, Zhao Q-G, et al (2006) Characteristics in the distribution of available cadmium in soil with analysis of its influential factors in fast economy developing region of south Jiangsu Province. *Resources and environment in the Yangtze Basin* 15:213–218 (in Chinese with English Abstract)
- Wang XS, Qin Y, Sang SX (2005a) Accumulation and sources of heavy metals in urban topsoils: a case study from the city of Xuzhou, China. *Environ Geol* 48:101–107
- Wang JM, Xu B, Hsieh CC, et al (2005b) Longitudinal trends of stomach cancer and esophageal cancer in Yangzhong County: a high-incidence rural area of China. *Eur J Gastroenterol Hepatol* 17:1339–1344
- Wu H, Yu R, Zeng B, et al (1990) Multivariate statistical analysis of aquatic environmental base line value of trace metal in the main stream of the Changjiang River. In: Zhang S, Zhang L, Tian L (eds) *The study on the background value of chemical elements in aquatic environment*, Mapping Press, Beijing, pp 260–278 (in Chinese)
- Yu K, Tasi L, Chen S, et al (2001) Chemical binding of heavy metals in anoxic river sediments. *Water Res* 35:4086–4094
- Yu KC, Chang CY, Tsai LJ, et al (2000) Multivariate analyses on heavy metal binding fractions of river sediments in Southern Taiwan. *Water Sci Technol* 42:193–199