COMPARATIVE ANALYSIS OF SOIL HEAVY METAL POLLUTION ON DIFFERENT ROADS: A CASE STUDY IN A TYPICAL INDUSTRIAL CITY OF CHINA

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Abstract. A total of 22 surface soil samples beside three different types of roads (trunk road, sub-trunk road and branch road) collected in Ma'anshan City, Anhui Province, China, were analyzed by inductively coupled plasma-atomic emission spectrometry (ICP-AES) and multivariate statistics. Besides, spatial distribution characteristics analysis was employed to identify the possible sources. The results indicate that the average concentrations of heavy metals following in the order of Mn > Pb > Co > Cr > As > Cd, and Cr content in the sub-trunk road are much lower than that in the trunk road and branch road. Geo-accumulation index shows that heavy metal pollution exists beside urban roads. Moreover, Cd pollution is the most serious, while Co and Pb are at a high pollution level. Potential ecological risk index shows that Cd poses a severe ecological risk; Pb and Co reach the medium ecological risk degree. Furthermore, two principal components (PC1 and PC2) of the heavy metal elements have been extracted by factor analysis, and the cluster analysis was consistent with the factor analysis. Based on spatial distribution characteristics, two sources have been identified: PC1 (Pb, Mn, Co) are contributed mainly by industrial pollution, and PC2 (Cd, As, Cr) are primarily influenced by traffic pollution.

Keywords: *trunk road, sub-trunk road, branch road, pollution assessment, spatial distribution characteristics, multivariate statistical*

Introduction

With the development of the automobile industry and transportation in China, the motorized travel mode of the public has experienced transformation from motorcycle to automobile, and the transportation structure has also undergone fundamental changes, making urban life increasingly convenient. According to statistics from the traffic management bureau of China's ministry of public security, by the end of the 2015 year, there were 279 million vehicles in the country, including 172 million automobiles. In 2015, the number of newly registered cars reached 23.85 million, and the net increase possessions was 17.81 million. However, the rapid development of roads and traffic also brings about a series of environmental pollution problems. For example, particulate matter containing heavy metals discharged by motor vehicles directly deposited in the road dust, or through wet and dry sedimentation deposited in the soil on both sides of the road, resulting in the accumulation of heavy metals in the soil and dust on both sides of the road. Especially in the current situation of poor vehicle emission performance and poor maintenance, heavy metal pollution problem is more prominent (Guo et al., 2008). Moreover, heavy metal is highly toxic and easy to accumulate in the soil, yet challenging to migrate and degrade. If the concentrations exceed a certain level, there will be higher biological toxicity. Once the soil is contaminated by heavy metals, it is

challenging to recover, causing serious damage to human body, environment, and even the whole food chain (Reza, et al., 2015; Hafeez, et al., 2019).

It is significant to clean the environment so as to avoid their entrance into the food chain because it is essential for protecting the health of animals and human beings. However, it is more realistic to understand the pollution status first, and then the sources of heavy metals, because not all of the heavy metals are released by anthropogenic activities, but they can also be produced by natural weathering processes of crust materials (Hashim, et al., 2011).

Pollution of soil in the current world is a major concern of the government and environment scientists, because of the importance of the soil for the survival and development of human society. Therefore, it is of great significance to analyze the pollution status of heavy metal elements in the soil along the traffic lines. Previous studies on heavy metals in soils on both sides of urban roads mainly focused on elements content, distribution characteristics, pollution status and ecological risk assessment (Afanasyeva, et al., 2019; Komendova, et al., 2018; Billah, et al., 2018; Sun, et al., 2015). However, there are few reports on the comparative study of soil heavy metal pollution besides different urban roads, especially in industrial cities. In this investigation, we selected trunk roads, sub-trunk roads and branch roads for systematic sampling and testing analysis in Ma'anshan city, a typical industrial city. In order to provide a scientific basis for the prevention and treatment of heavy metal pollution caused by highway traffic.

Materials and methods

Study area

Ma'anshan City is a steel industrial city that has risen since the late 1950s. It is located on the south bank of the lower Yangtze River and in the eastern part of Anhui Province, China. The longitude is from 118°21'38" to 118°52'44", and the latitude is from 31°46'42" to 31°17'26". Influenced by the humid climate of the northern subtropical monsoon, the city has an annual average precipitation of 1100 mm, and an annual average temperature of 15.7 degrees (centigrade). In 2015, the city's registered population was 2.277 million, and the urban resident population was 880,000. Ma'anshan City is located in the middle and lower reaches of the Yangtze River polymetallic metallogenic belt. This area is rich in mineral resources, and the main metal minerals are iron, vanadium, copper, gold, cobalt, which provide guarantee the development of local steel industry. The local manufacturers are mainly dominated iron and steel, special-purpose vehicles, high-grade cardboard, new process carbon black, electronic materials, biomedical, textile clothing, green food. Ma'anshan Iron & Steel Group is a large-scale steel joint enterprise and an important steel production base, as well as one of the largest industrial enterprises in Anhui Province. Geographical location of the study area is shown in *Figure 1*.

Sampling sites and sample collection

According to the urban road planning of the study area, the vehicle design speed of the trunk roads is 60 km/h, the number of vehicle lanes is 5~8, and the width of the road is 45~55 m. The design speed of motor vehicles on the sub-trunk roads is 40 km/h, the number of motor vehicle lanes is 4~6, and the width of the road is 40~50 m. As for the

branch roads, the design speed of motor vehicles is 30 km/h, the number of motor vehicle lanes is 3~4, and the width of the road is 15~30 m. Before sampling, the trunk roads, sub-trunk roads and branch roads in Ma'anshan city are divided according to the geographical location and the flow of motor vehicles. The trunk road is the main road connecting the main urban districts, mainly including Huolishan Avenue, Jiangdong Avenue, Cihuhar Road, Jiuhua Road, Yinshan Road, Yushan Road and the railway line crossing the city. The sub-trunk road is a large number of general traffic roads in the city, which coordinates with the trunk road to form the urban trunk roads network, and plays the role of connecting various parts and distributing traffic, mainly including Hongqi Road, Jiashan Road, Huayu Road, Pingshan Road, Kangle Road. The branch road is an important part of the road system, mainly undertaking short-distance traffic, including Hunan West Road, Jiuhua West Road, Park Road, Xiyuan Road, Pinghu Road, Yucai Road and so on.

Figure 1. Geographical location and sampling distribution of the study area

In this study, samples collection was performed in December, 2015. Plant mulch and topsoil were removed before sample collection, and the sampling depth is 15 cm. For each soil sample, five sub-samples were collected from different cells within a grid of approximately 5 m² to form a composite sample to enhance the representativeness of the sample for each sampling site. The samples were stored in polyethylene packages that were transported back to the lab for chemical analysis. The samples were numbered sequentially on the bag. At the same time, GPS was used to determine the location of each sample point. A total of 22 surface soil samples were collected, including 11 trunk roads, 6 sub-trunk roads and 5 branch roads. Soil samples were firstly air-dried in the natural condition, sifted to remove stone and plant root debris, then ground to pass through a 200-mesh sieve.

Experimental method

(1) The authors weighed 0.1 g soil powder by electronic balance scale and put the soil into a tetrafluoroethylene digestion tank. Besides, 1 mL concentrated nitric acid, and 1 mL hydrofluoric acid is subsequently added. The authors put the sealed digestion tank in the steel sleeve, tightened the lid, and put it into the oven (190 °C) to heat for 20 h. Then take the steel sleeve out of the oven for cooling, take out the digestion tank, heat it on a hot plate (140 °C) to near dry, add 4 mL concentrated nitric acid and 4 mL of deionized water. Then put the digestion tank into the steel sleeve, tighten the lid, put it in the oven at 150 °C for 2 h, take out the steel can for cooling. After cooling, remove the digestion tank, transfer the liquid from the digestion tank into a 100 mL volumetric bottle, and wash the polytetrafluoroethylene with a certain amount of deionized water for 2 to 3 times. All the washing liquid is poured into the volumetric flask. Finally, the nitric acid solution was prepared, in which concentrated nitric acid 2 mL and deionized water 98 mL were used to titrate the volumetric flask.

(2) Using ICP-AES to determine the volume of solution in a volumetric flask, the internal standard of the element was selected, and the calibration curve was drawn. The concentration in the sample solution was calculated by regression equation to determine the heavy metal element content of the soil.

The above analysis and test were carried out at the Engineering Research Center of Coal Exploration, Anhui Province, China.

Analysis methods

Geoaccumulation index

The geoaccumulation index, also known as the Muller index, was proposed by German scientist Muller and developed in Europe as a quantitative index to study heavy metal pollution in sediments and other substances. The index of geoaccumulation (I_{geo}) ensures the assessment of contamination degrees by comparing the current and pre-industrial concentrations (Muller, 1969), and is calculated as follows.

$$I = \log_2 [C_n / KB_n] \quad (\text{Eq.1})$$

In *Equation 1*, C_n means the measured content of the element in the sediment; B_n represents the geochemical background value; and K is the coefficient obtained by considering the variation of the background value that may be caused by the rocks differences in different places (in general, the K value is 1.5). Moreover, the geoaccumulation index is classified as *Table 1*. This method takes into account not only human-made pollution factors and environmental geochemical background values but also takes into account the factors that may change background values due to natural diagenesis, which makes up for the shortcomings of other evaluation methods effectively (Jia, et al., 2009; Chai, et al., 2006)

Potential ecological risk index

Potential ecological risk index is a method for evaluating the pollution degree of heavy metals in soil or sediments and their potential ecological hazards. The potential ecological risk index can calculate as follows.

$$C_f^i = C_s^i / C_n^i \quad (\text{Eq.2})$$

$$E_r^i = T_r^i \times C_f^i \quad (\text{Eq.3})$$

$$RI = \sum_{i=1}^n E_r^i \quad (\text{Eq.4})$$

In *Equation 2*, C_f^i means the enrichment coefficient of heavy metal; C_s^i means the concentration of heavy metal in the sample; C_n^i means the reference value, generally taking the national or local environmental standard value in soil as the reference value (Fan et al., 2010); In *Equation 3*, E_r^i means the potential ecological hazard coefficient of individual; T_r^i means the toxicity response coefficient of heavy metal, the toxicity response coefficients were $\text{Cd} = 30 > \text{As} = 10 > \text{Pb} = \text{Co} = 5 > \text{Cr} = 2 > \text{Mn} = 1$ (Aiuppa, et al., 2003; Armagan, et al., 2008), respectively; In *Equation 4*, RI means the potential of ecological risk of multiple metals. The classification criteria of heavy metals potential ecological risk index are listed in *Table 2*.

Table 1. Classification of index of geoaccumulation

I_{geo}	Classification	Degree of pollution
$5 < I_{geo} \leq 10$	6	Extremely serious pollution
$4 < I_{geo} \leq 5$	5	Strong-extreme pollution
$3 < I_{geo} \leq 4$	4	Strong pollution
$2 < I_{geo} \leq 3$	3	Medium-strong pollution
$1 < I_{geo} \leq 2$	2	Medium pollution
$0 < I_{geo} \leq 1$	1	Light pollution
$I_{geo} \leq 0$	0	No pollution

Table 2. Ranking standard of potential ecological risk hazards

E_r^i	Single ecological hazard	RI	Overall ecological hazard
< 40	Low	< 150	Low
40~80	Moderate	150~300	Moderate
80~160	Heavier	300~600	Heavy
160~320	Heavy	> 600	Serious
> 320	Serious		

This method not only considers the content of heavy metals in soil, but also considers the migration rule of toxicity of heavy metals in soil, the sensitivity to heavy metal pollution, and the difference of background value of heavy metals, eliminating the influence of regional differences. The degree of potential ecological risk of heavy metals classified reflects the characteristics of bioavailability, relative contribution, spatial differences and so on. Generally, potential ecological risk index is a comprehensive indicator reflecting the potential impact of heavy metals on the ecological environment (Fan et al., 2010).

Multivariate statistical analysis

Multivariate statistical analysis is a method of using mathematical statistics to study multivariate problems. It includes regression analysis, discriminant analysis, cluster analysis, principal component analysis, factor analysis, correspondence analysis and so on. It has been widely applied in education, medicine, economics, environmental science and other disciplines. Multivariate statistical analysis provides an alternative method to identify pollution sources, and many scholars use this method to identify the pollution sources of soil or sediment (Aiuppa, et al., 2003; Armagan, et al., 2008; Reisenhofer, et al., 1996; Sun, et al., 2012).

Factor analysis uses a few factors to describe the relationship between multiple indicators, several same-class variables with relatively close correlations with each type of variable becoming a factor, and fewer factors reflecting most of the original information (Zhang, 2004). The general steps are summarized as follows: (1) standardizing raw data, which does not change the correlation coefficients between variables, and eliminate the influence of different variables dimension; which not change the correlation coefficient between variables, on the contrary, it can eliminate the influence of the dimension of different variables. (2) calculating the correlation coefficient matrix of the normalized data and its corresponding eigenvalues and eigenvectors; (3) using the maximum variance method for orthogonal rotation. This process can make the factor load polarized, which easy to find the information represented by the factor; (4) determining the number of factors, calculating the score of factors, and making corresponding statistical analysis.

Cluster analysis is a simple multivariate analysis method that classifies the research objects according to their characteristics (Zhang, 2004). The basic idea of cluster analysis is to use quantitative statistical analysis method to find some statistics that can measure the degree of affinity between samples or variables. Subsequently, based on these statistics, some samples (or variables) with greater similarity are aggregated into one group and others (or variables) are aggregated into another group.

The multivariate statistical analysis methods mentioned above are all completed by International Business Machines Corporation (IBM) SPSS software. IBM SPSS is a software product and related service program developed by IBM for statistical analysis, data mining, predictive analysis, and decision support tasks. It has been applied to various fields of natural science, technological science, and social science.

Visualization analysis

SigmaPlot is an advanced statistical analysis and scientific drawing software developed by Systat Software Company. The software integrates graphics drawing and data analysis. It has been applied to medicine, life sciences, engineering and environmental sciences due to its simple operation and high efficiency. In this study, SigmaPlot software (version 12.5) was used to construct a three-dimensional model of the spatial distribution of heavy metals in the soil of Ma'anshan city of Anhui Province, China.

Results

Content characteristics of heavy metals

The statistical analysis results of heavy metals in both sides along the road in Ma'anshan city of China are shown in *Table 3*, and the statistical analysis of the data was performed by

IBM SPSS statistic software (version 19). According to *Table 1*, the contents of soil heavy metals in this area varied in a certain range. Among them, Pb content ranged from 193 to 711 ug/g (average 463 ug/g); Cd content ranged from 6.8 to 22.25 ug/g (average 12.55 ug/g); Co content ranged from 284 to 395 ug/g (average 349 ug/g); As content ranged from 2.25 to 63.85 ug/g (average 49.21 ug/g); Mn content ranged from 298 to 717 ug/g (average 467 ug/g); and Cr content ranged from 3.05 to 253 ug/g (average 85.19 ug/g), respectively. The contents following the order of Mn > Pb > Co > Cr > As > Cd.

Table 3. Statistical analysis of heavy metals in soils (ug/g)

	Pb	Cd	Co	As	Mn	Cr
Minimum value	193	6.8	284	2.25	298	3.05
Maximum value	711	22.25	395	63.85	717	253
Mean value	463	12.55	349	49.21	467	85.19
Standard deviation	168	4.94	34.11	15.55	119	84.31
Variance	28285	24.44	1164	241.75	14126	7108
Coefficient of variation (CV)	0.36	0.39	0.1	0.32	0.25	0.99
Skewness	-0.013	0.986	-0.615	-2.189	1.141	0.825
Kurtosis	-1.266	1.13	-0.593	5.77	0.413	0.433
Soil background value Ma'anshan (Liu, 2012)	24.43	0.264	—	10.553	—	86.4
Soil background value in Anhui (Environmental Monitoring of China, 1990)	26.6	0.07	16.3	9	530	66.5
Nationals soil background value (Environmental Monitoring of China, 1990)	26	0.08	12.7	11.2	583	61

Coefficient of variation (CV, represents the ratio of the standard deviation to the mean) is an index that can be used for identifying the anthropogenic contribution degree for pollution in environmental studies (Sarkar, et al., 2010; Sun, et al., 2017), previous studies revealed that when $CV < 0.10$ and > 0.90 mean low and high anthropogenic contributions, respectively. In this study, the CV of the elements in the study area are following in the turn: Cr > Cd > Pb > As > Mn > Co, and Cr reached 0.99, which was a strong variation, while Mn, Pb, Co, Cr, As and Cd were relatively low (< 0.40). The results indicate that anthropogenic activities have probably influenced the soil to a certain degree.

Figure 2 shows the distribution of heavy metal elements in different types of road. The contents of Pb, Co and Mn in the soils on both sides of trunk roads, sub-trunk roads and branch roads are higher and its differences are smaller, while the contents of Cd, As and Cr are relatively lower. The contents of Cr in sub-trunks road are much lower than those in trunks road and branch road.

Pollution assessment

In this study, Ma'anshan City soil background value, Anhui Province soil background value and Chinese national soil background value were selected value for reference (*Table 3*). Geo-accumulation index analysis on both sides of different roads in Ma'anshan urban area was conducted, and the results show in *Table 4* and *Figure 3*, I_{geo-1} , I_{geo-2} and I_{geo-3} represent the geoaccumulation indexes calculated by the soil background values of Ma'anshan city, Anhui Province and Chinese, respectively.

Figure 2. Distribution of heavy metal elements in different types of road

Table 4. Soil heavy metals in different roads on both sides of the geo-accumulation index

	Trunk roads	Sub-trunk roads	Branch roads	Trunk roads	Sub-trunk roads	Branch roads	Trunk roads	Sub-trunk roads	Branch roads
	I_{geo-1}			I_{geo-2}			I_{geo-3}		
Pb	3.63	3.64	3.78	3.51	3.52	3.66	3.54	3.55	3.69
Cd	5.23	4.45	5.23	7.15	6.36	7.14	6.96	6.17	6.95
Co	-	-	-	3.82	3.90	3.79	4.18	4.26	4.15
As	1.53	1.76	1.81	1.76	1.99	2.04	1.45	1.67	1.72
Mn	-	-	-	-0.74	-0.83	-0.79	-0.88	-0.96	-0.92
Cr	-0.06	-4.54	-0.97	0.32	-4.16	-0.59	0.45	-4.04	-0.47

According to Table 4, no matter which soil background value is taken as reference, soil heavy metals on both sides of urban trunk roads, sub-trunk roads and branch roads have a certain degree of pollution. The Cr and Mn element are non-polluting in the branch roads and the secondary trunk roads. For the trunk roads, if we refer to the soil background value of Ma'anshan City, Cr is non-polluting, if we compare with Anhui Province soil background value and the national soil background value, Cr belongs to mildly polluted. It indicates that the Mn element has not been polluted, Cr element has not been polluted or intensively polluted, and the overall condition is good. Co and Pb were strong pollutions, and Cd was a strong-extremely pollution level in the soil samples on both sides of the urban road in Ma'anshan City.

Risk assessment

The potential ecological risk index of heavy metals pollution in soils on both sides of different roads in Ma'anshan urban area is shown in Table 5. According to Table 5, the potential ecological hazard coefficients of each element follow the order of $Cd > Co > Pb > As > Cr > Mn$, which is consistent with the results of the geo-accumulation index method. Among them, Cd reached a severe degree of ecological risk, Pb, Co was a relatively severe degree of ecological risk, As was a moderate degree of ecological risk, Mn, Cr was a low degree of ecological risk. Besides, for the overall potential ecological hazard index (RI), the ecological risk of the sub-trunk road is lower than that of the trunk road and the branch road, but they also have reached the level of potential severe ecological risk. Therefore, the soil heavy metal pollution on both sides

of the road in Ma'anshan city is a potential severe ecological hazard, and even Pb, Co has reached a relatively severe ecological risk. Therefore, in the process of soil environmental treatment in the future, we should strengthen the management of Cd, Pb and Co.

Table 5. Potential ecological risk index of heavy metals on both sides of the road

	E_r^i						RI
	Pb	Cd	Co	As	Mn	Cr	
Trunk roads	87.51	5592	136	40.94	0.82	4.09	5861
Sub-trunk roads	88.02	3238	143.4	47.87	0.77	0.18	3518
Branch roads	97.11	5569	133.3	49.53	0.79	2.17	5852

Discussion

From the previous analysis, we can find that there is an interesting phenomenon here, that is, in the soil on both sides of the road in the study area, the concentration of heavy metals in the branch road is higher than that in the sub-trunk road, or even similar to that in the trunk road. The main reason we consider is that the traffic conditions of the branch roads are not as good as those of the main and secondary roads. According to China Urban Road Engineering Design Code (Ministry of Housing and Urban-Rural Construction of the People's Republic of China, 2016), the width of branches is generally 15-20 m, while the width of sub-trunk and trunk roads can reach 40-55 m, which directly determines the speed of motor vehicles on the road. Generally speaking, the speed of branches is lower than 30 km/h or even lower. However, the sub-trunk road can reach 30-50 km/h and the trunk road can reach 60 km/h. Therefore, in the process of driving on the branch road, automobiles are bound to brake frequently and even start their cars. Brake, brake and tire wear will inevitably lead to the increase of heavy metal content, which makes the heavy metal content of branch road higher than that of sub-trunk road.

In addition, soil heavy metals are not only related to the background value of bedrock (or parent material), but also influenced by the mode and intensity of human activities. According to the analysis above, soil heavy metals in this area are polluted to some extent. In order to identify pollution sources effectively, factor analysis was carried out for heavy metals. According to the eigenvalue and cumulative variance contribution rate, two factors were extracted (*Table 6*). The explanations of variance were 49.512%, 36.764%, respectively, and the complete explanations of cumulative variance were 86.277%. For the sake of understanding the information represented by each principal component, the factors are rotated using the maximum variance method (*Table 6*). According to *Table 6* and *Figure 3*, PC1 is controlled by Cd, As, and Cr, and PC2 is controlled by Co, Mn and Pb.

Xie (2010) holds that Cd mainly originates from industrial activities, such as smelting, electroplating, batteries, metal processing and so on. The sources of Cd in soil are mainly attributed to natural and human activities. The former mainly comes from the background values of rocks and soils, while the latter mainly comes from industrial "three wastes" (waste water, waste gas, and waste residue) and large amounts of Cd-containing fertilizers. Industrial waste gas is the main source of air Cd pollution. The content of Cd in the air of remote areas is generally lower than 1.0 pg/mL, but the

concentration of Cd in the atmosphere around industrial areas is higher (Zeng, et al., 2005). Dry and wet deposition of Cd contaminants in the atmosphere is also a significant import cause of soil Cd pollution. Higher concentrations of Cd can enter the soil through rainfall or sedimentation. Plants absorb some of Cd and cause pollution, and the remained Cd accumulates in the soil. Combining the actual situation of iron and steel industry in Ma'anshan city and the spatial characteristics of Cd, As and Cr (Fig. 4), it can be concluded that factor 1 is affected by industry. Lead is a tracer element of automobile exhaust emissions (Lv, et al., 2013). In general, The background value of a lead in the environment is very low, and lead is mainly derived from tetraethyl lead anti-explosive agent in gasoline. However, the gasoline combustion process can be decomposed to produce inorganic lead and lead-containing oxides. After being discharged from the vehicle exhaust, it settles in the soil on both sides of roads through the atmosphere. According to this, PC2 can be expressed as the impact of road traffic. So far, it can be concluded that the primary sources of Cd, As and Cr in soils on both sides of urban roads are industrial “three wastes”, while the emission of urban traffic exhaust and the wear of urban tires are the essential sources of Pb, Mn and Co pollution in soil samples.

Table 6. Total variance explained and component matrices for heavy metal contents

Components	Initial Eigenvalues			Extracting sums of squares			Extraction sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	3.007	50.112	50.112	3.007	50.112	50.112	2.971	49.512	49.512
2	2.17	36.165	86.277	2.17	36.165	86.277	2.206	36.764	86.277
			Component matrix		Rotated component matrix				
							PC1	PC2	
			Pb	-0.313	-0.84	Pb	-0.133	-0.887	
			Cd	0.979	0.067	Cd	0.944	0.268	
			Co	-0.329	0.924	Co	-0.513	0.835	
			As	0.865	-0.257	As	0.9	-0.072	
			Mn	0.447	0.723	Mn	0.288	0.8	
			Cr	0.945	-0.133	Cr	0.952	0.066

Figure 3. Factor loading of soil heavy metal sources

Figure 4. Spatial distribution characteristics of Cd, As and Cr

In order to verify the accuracy of the factor analysis method, the soil heavy metal elements were clustered (Fig. 5). Clustering results are ideal, and can be divided into three categories: Cd-Cr-As, Co-Mn, Pb clustered into a single group, consistent with the results of factor analysis.

Figure 5. Cluster analysis of soil heavy metals

Conclusion

The contents of heavy metals in soils on both sides of roads in Ma'anshan city changed within a certain range, and the average contents were following in the order of $Mn > Pb > Co > Cr > As > Cd$ from large to small. For the soils on both sides of different types of roads, the content of Pb, Co and Mn is higher than that of Cd, As and Cr, and the concentrations of Cr in sub-trunk roads is lower than that of trunk roads and branch roads.

Pollution assessment showed that heavy metals in the soil on both sides of urban trunk roads, sub-trunk roads and branch roads were polluted to a certain extent. Mn is no pollution; Cr element had not been polluted or intensity pollution, the overall situation was good; Co, Pb belonged to strong pollution level; Cd belonged to the severe pollution level.

The risk assessment showed that Cd was a severe ecological risk, Pb and Co was a severe ecological risk, As was a moderate ecological risk, Mn and Cr was a low ecological risk. According to the total potential ecological hazard index, the ecological risk of the sub-trunk road is lower than that of the main road and the sub-trunk road, which has reached a severe potential ecological risk degree. In the future soil quality management process, it is particularly necessary to strengthen the management of cadmium, lead and cobalt pollution.

Two principal components of the six heavy metal elements have been extracted by factor analysis. Combining with the spatial distribution characteristics of heavy metals, two sources have been identified, PC1 (Pb, Mn, Co) and PC2 (Cd, As, Cr). The former are contributed mainly by industrial pollution, while the latter are primarily influenced by traffic pollution.

Recommendations

Taking Ma'anshan City, Anhui Province as an example, this paper discussed the pollution status and sources of heavy metals in soil along the trunk roads, sub-trunk

roads and branch roads of the city, which has a certain practical significance for the prevention and control of heavy metals pollution in urban soil. In the future research, we need to pay more attention to the study of heavy metal pollution level and occurrence in road ash layer, rainfall and other media. We can even make a comparative study of the heavy metal pollution in the soil on both sides of different roads in industrial and non-industrial cities, so as to explore the impact of different types of cities and different specifications of road traffic activities on the distribution of heavy metals, and evaluate their pollution, so as to provide theoretical support for the prevention and control of heavy metal pollution.

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