http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 13 (9): 1577-1590, 2014
ISSN 1812-5638 / DOI: 10.3923/itj.2014.1577.1590

Analysis of Heavy Metal Pollution in Urban Topsoil

[1]Yalin Miao, [1]Xin Ji, [2]Wei Wei and [1]Wen Wen
[1]College of Science,
[2]School of Computer Science and Engineering, Xi'an University of Technology, Xi'an, 710048, China

Abstract: With the rapid development of economic and the increasingly urban populations, the impacts of humans' activities on the environment quality of the city is prominently increased. In this study, for the spatial distribution and concentration of the sampling points of heavy metal elements in the city, evaluate soil heavy metal pollution by using Single-factor index method, Nemero index method and cumulative index method, determine the main causes of pollution in each region by the cluster analysis method and the principal component analysis method. Finally, we get the position coordinates of pollution sources in the city by building and solving the three dimensional partial differential model of migration of heavy metal pollutants in soil environment system. In order to provide better research for the evolution model of the urban geology environment, we collected more information and evaluate the advantages and disadvantages of the models.

Key words: Soil heavy metal, single-factor index method, nemero index method, cluster analysis method, principal component analysis method, partial differential model, pollution

INTRODUCTION

In the past, soil pollution is not as highly valued as air pollution and water pollution. The soil pollution is often wide and volume and is more difficult to control and governance than air pollution and water pollution. However, after effectively governance of air and water pollution, the seriousness and urgency of soil pollution in the developed country is fully revealed.

At present, method to improve and manage the heavy metal pollution contaminated with precipitation, elution method, antagonistic method, electrochemical method and magnetization method. These methods have common disadvantage include investment cost is too high and can only be used for the place of very seriously pollution. And the analysis before only use cluster analysis and principal component analysis is rarely consider the human factors in the cause of pollution, in this study, we solve the influence of artificial factors based on the use of cumulative index method. The propagation characteristics of pollutants are analyzed with the degree of the pollution deviation from and the center, the obtained characteristics is that by the center spread to the surrounding, along with the increase of distance, the more distance far from the heavy pollution area and the more degree of heavy metals pollution decreased. Generally, we rarely focus on the soil water migration and movement of soil heavy metal, in this study, we consider the soil heavy metal pollutants in the process of migration also will be affected by the chemical and physical properties of soil water and solute itself and other chemicals in the soil and treat the factors as the main basis of pollutant transmission characteristics, establish three dimensional partial differential model, calculate each direction changes of the concentration accurately, provide a more reliable method to determine the location of pollution sources.

In this study, Along functional lines, urban area can generally be divided into living areas, industrial areas, mountain areas, trunk roads, parks district and so on, respectively, are recorded as class 1 area, class 2 area,... and class 5 area, different areas affected by human activities to varying degrees. Now, we carry out the investigation of geologic environment of the soil in the city. Therefore, the study area is divided into the grid area intervals of 1 km, getting sample and number according to 1 sampling points per square kilometer of topsoil sampling (0-10 cm depth) and using GPS to record the position of the sampling point. Application of special equipment testing analysis, we obtain every sample contained many kinds of chemical elements concentration data. Using special test equipment to analysis, the concentration data of various chemical elements contained in each sample was obtained. On the other hand, sampling according to the distance 2 km away from people and industrial activities in the natural area and use the result as the background value of elements of urban topsoil. The obtained data include, (1) Location, altitude and its subordinate function area information of 319 sampling

Corresponding Author: Yalin Miao, College of Science, Xi'an University of Technology, Xi'an, 710048, China

point; (2) A list of concentration of 8 kinds of heavy metals (As, Cd, Cr, Pb, Hg, Cu, Ni, Zn) in the sampling point. (3) Lists the background values of 8 main elements of heavy metal (specific data in the appendix 1). In this study, we build the mathematical model and analysis the soil heavy metal pollution according to the obtained information.

MATERIALS AND METHODS

ANALYSIS ON SPATIAL DISTRIBUTION AND POLLUTION DEGREE OF HEAVY METALS

This study presents five different environmental region of a city, in consist of living areas, industrial areas, mountain areas, trunk roads and parks district and concentration values of large number of sampling points and the 3D coordinates (specific data in appendix), due to the discrete degree of sampling point distribution, it is necessary to use excel to select and integrate the large amounts of data, result in the scatter distribution of the five regional sampling points in Fig. 1.

In order to get spatial distribution map of heavy metals more specific, we use concentration distribution of eight kinds of heavy metal in consist of As, Cd, Cr, Cu, Hg, Ni, Pb and Zn and the three-dimensional map of terrain distribution of five regions in consist of living areas, industrial areas, mountain areas, trunk roads and parks district to instruct. First the concentration distribution map of eight kinds of heavy metals in the city are obtained by interpolation function (Yue and Wang, 2012) reference in MATLAB (Li, 2012) in Fig. 2-9.

Then get the 3D terrain distribution map of five area in the city by interpolation function in MATLAB in Fig. 10.

Since each region has eight kinds of heavy metals, the evaluation model is divided into Single-factor index method and the Nemero (Zhu *et al.*, 2012) index method. First of all, establish single exponential for pollution:

$$I_i = \frac{(C_i - B)}{(S_i - B)} \tag{1}$$

Type in: i take 1-8, respectively corresponding to eight kinds of elements in consist of As, Cd, Cr, Cu, Hg, Ni, Pb and Zn, I_i is the index of pollution elements i, C_i is the average concentration of elements i in the region, S_i is the national evaluation standard of element i, B is background values of element i in the soil. Then i kind of pollution elements in partial of five regions obtained by solving the single pollution index in Table 1-5. (Note: The unit for heavy metal elements is μg g^{-1}).

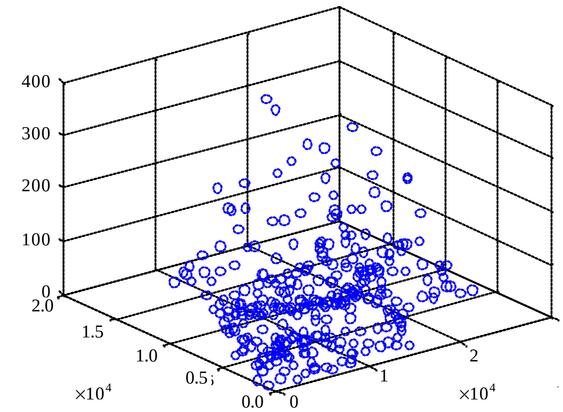

Fig. 1: Scatter distribution after the selection of sampling points

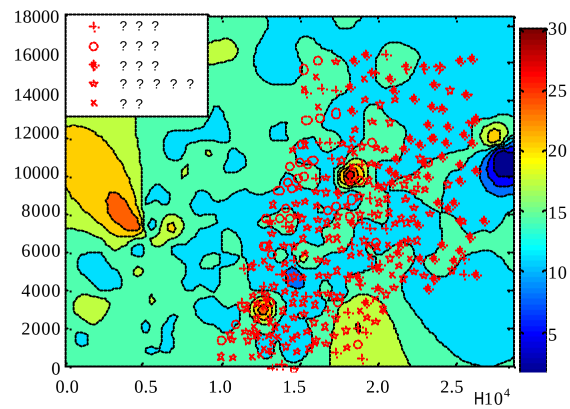

Fig. 2: Concentration distribution of As

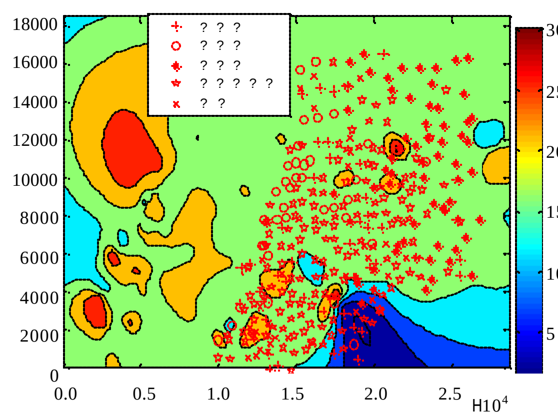

Fig. 3: Concentration distribution of Cd

Nemero index method: The Single-factor index method (Xu *et al.*, 2007) result in the pollution degree of heavy metals in each region, in order to obtain the

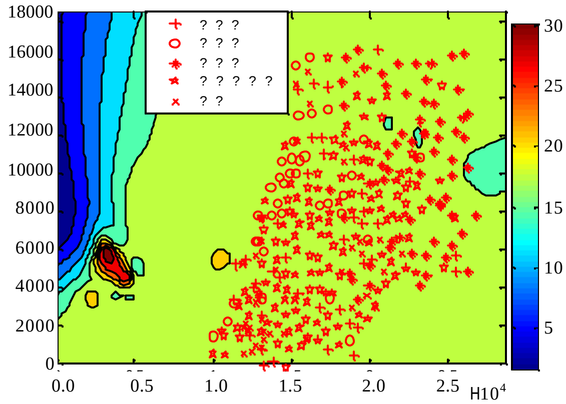

Fig. 4: Concentration distribution of Cr

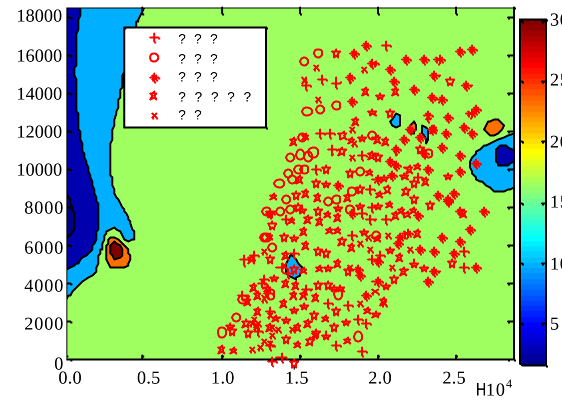

Fig. 7: Concentration distribution of Ni

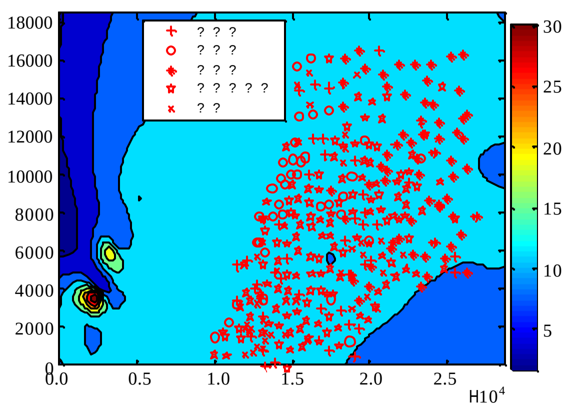

Fig. 5: Concentration distribution of Cu

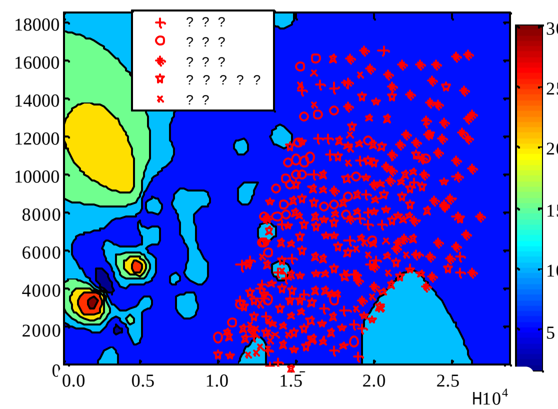

Fig. 8: Concentration distribution of Pb

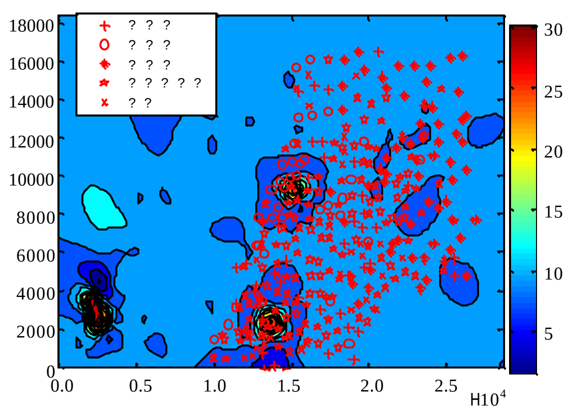

Fig. 6: Concentration distribution of Hg

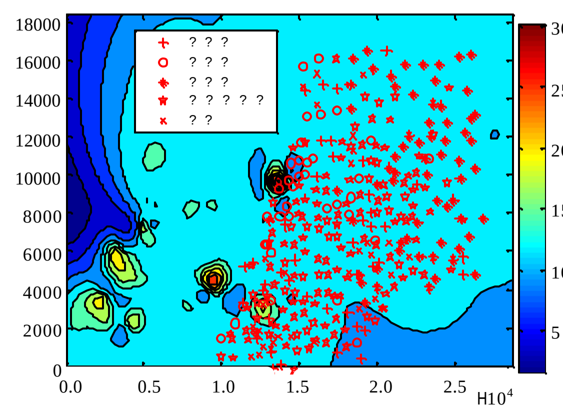

Fig. 9: Concentration distribution of Zn

comprehensive pollution level of each region, we use the Nemero index method Nemero index expression:

$$P = \sqrt{\left[0.5\times\left[\left(I_{Avg}\right)^2+\left(I_{Max}\right)^2\right]\right]} \quad (2)$$

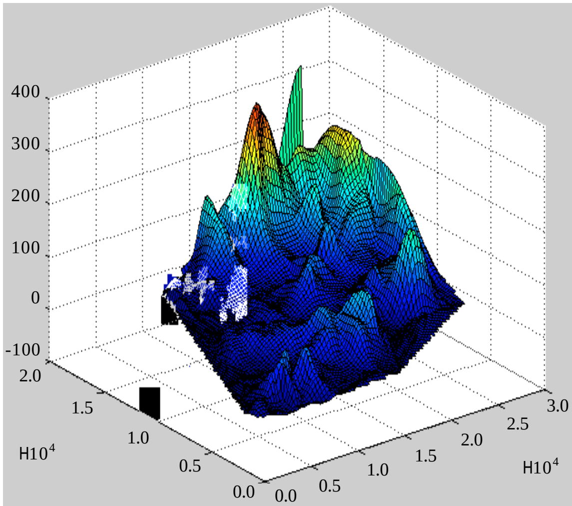

Fig. 10: Terrain map of 5 areas

Table 1: Element of living area

	Living areas			
Elements	Si	Ci	B	Ii
As	3.6	6.27	30.0	0.101136
Cd	130	289.96	300.0	0.940941
Cr	31	69.02	250.0	0.173607
Cu	13.2	49.40	35.0	1.660550
Hg	0.035	0.09	00.3	0.218868
Ni	12.3	18.34	40.0	0.218051
Pb	31	69.11	250.0	0.174018
Zn	69	237.01	200.0	1.282519

Table 2: Element of industrial areas

	Industrial areas			
Elements	Si	Ci	B	Ii
As	3.6	7.25	30.0	0.138258
Cd	130	393.11	300.0	1.547706
Cr	31	53.41	250.0	0.102329
Cu	13.2	127.54	35.0	5.244954
Hg	0.035	0.64	00.3	2.290566
Ni	12.3	19.81	40.0	0.271119
Pb	31	93.04	250.0	0.283288
Zn	69	277.93	200.0	1.594885

Table 3: Element of mountain areas

	Mountain areas			
Element	Si	Ci	B	Ii
As	3.6	4.04	30.0	0.01667
Cd	130	152.32	300.0	0.13129
Cr	31	38.96	250.0	0.03635
Cu	13.2	17.32	35.0	0.18899
Hg	0.035	0.04	00.3	0.01887
Ni	12.3	15.45	40.0	0.11372
Pb	31	36.56	250.0	0.02539
Zn	69	73.29	200.0	0.03275

Type in: P is the comprehensive pollution index, I_{Avg} is the average value for each element of pollution index, I_{Max} is the maximum value of each element of pollution index. The comprehensive pollution index of each region is obtained by solving the Nemero index formulation in Table 6 and 7.

Table 4: Element of trunk roads

	Trunks roads			
Elements	Si	Ci	B	Ii
As	3.6	5.71	30.0	0.079924
Cd	130	360.01	300.0	1.353000
Cr	31	58.05	250.0	0.123516
Cu	13.2	62.21	35.0	2.248165
Hg	0.035	0.45	00.3	1.554717
Ni	12.3	17.62	40.0	0.192058
Pb	31	63.53	250.0	0.148539
Zn	69	242.85	200.0	1.327099

Table 5: Element of parks district

	Parks district			
Elements	Si	Ci	B	Ii
As	3.6	6.26	30.0	0.100758
Cd	130	280.54	300.0	0.885529
Cr	31	43.64	250.0	0.057717
Cu	13.2	30.19	35.0	0.779358
Hg	0.035	0.12	00.3	0.301887
Ni	12.3	15.29	40.0	0.107942
Pb	31	60.71	250.0	0.135662
Zn	69	154.24	200.0	0.650687

Table 6: Comprehensive pollution index of each area

Areas	I Max	I AVG	P
Living areas	1.660550	0.596230	0.882173
Industrial areas	5.244954	1.434308	2,718,767
Mountain areas	0.188991	0.070955	0.100936
Trunk road	2.248165	0.878292	1.206819
Park district	0.885529	0.377438	0.481306

Table 7: Pollution standard classification

Index range	Pollution level	Index range	Pollution level
<0	Background	1.5-2.0	Medium pollution
0-0.5	Clean	2,0-2,5	Deep pollution
0.5-1.0	Alert	2,5-3,0	Serious pollution
1.0-1.5	Light pollution	>3.0	Most serious pollution

Cumulative index method: Although the Single-factor index method (Yang *et al*., 2007a) and the Nemero index method can be more comprehensive evaluation for heavy metal pollution level of soil, since this two kind of method cannot separate the artificial exception from the natural exception, the cumulative index method make up for its insufficient, the cumulative index method expression is:

$$\text{Igeo} = \log_2\left[\frac{C_n}{(k \times B_n)}\right] \tag{3}$$

Type in: Igeo is the cumulative index, C_n is the average of element n in each region, B_n is the geochemistry background value of element n, k is the coefficient of the change of background that lead by different rock in each areas (value = 1.5). Result in the degree of heavy metals pollution in each area by solving the cumulative index expression in Table 8.

Table 8: Pollution degree of heavy metals in each area

	Heavy metal elements			
Parameters	As	Cd	Cr	Cu
Cumulative index	0<0.2155 = 1	0<0.5724 = 1	0<0.5698 = 1	1<1.3190≤2
Pollution degree	Light pollution	Light pollution	Light pollution	Light pollution
Cumulative index	0<0.4250 = 1	1<1.0115 = 2	0<0.1999 = 1	2<2.6874≤3
Pollution degree	Light pollution	Medium pollution	Light pollution	Medium serious
Cumulative index	-0.4186≤0	-0.3564 ≤0	-0.2552≤0	-0.1931≤0
Pollution degree	None pollution	None pollution	None pollution	None pollution
Cumulative index	0<0.0805 = 1	0<0.8846 = 1	0<0.3201 = 1	1<1.6516≤2
Pollution degree	Light pollution	Light pollution	Light pollution	Medium pollution
Cumulative index	0<0.2132 = 1	0<0.5247 = 1	-0.0916≤0	0<0.6086≤1
Pollution degree	Light pollution	Light pollution	None pollution	Light pollution
Heavy metal elements	Hg	Ni	Pb	Zn
Cumulative index	0<0.8255 = 1	-0.0086≤0	0<0.5717 = 1	1<1.1953≤2
Pollution degree	Light pollution	None pollution	Light pollution	Medium pollution
Cumulative index	3<3.6130 = 4	0<0.1026 = 1	1< 1.0006 = 2	1<1.4251≤2
Pollution degree	Serious pollution	Light pollution	Medium pollution	Medium pollution
Cumulative index	-0.3581≤0	-0.2560≤0	-0.3470 ≤0	-0.4979≤0
Pollution degree	None pollution	None pollution	None pollution	None pollution
Cumulative index	3<3.0893 = 4	-0.0664≤0	0<0.4502 = 1	1<1.2304≤2
Pollution degree	Serious pollution	None pollution	Light pollution	Medium pollution
Cumulative index	1<1.1311 = 2	-0.2710≤0	0<0.3847 = 1	0<0.5755≤1
Pollution degree	Medium pollution	None pollution	Light pollution	Light pollution

Evaluation results: Analyze the degree of heavy metals pollution in different regions of the city through the Nemero index method and the cumulative index method, result in that, in living areas, elements As, Cd, Cr, Hg and Pb belong to light pollution, element N_i belongs to none pollution, elements Cu and Zn belong to medium pollution, comprehensive pollution level is alert level. In industrial areas, elements As, Ni and Cr belong to light pollution, elements Cu, Pb, Zn and Cd belong to medium pollution, Hg belongs to serious pollution, comprehensive pollution level is serious level. In mountain areas, elements As, Cd, Cr, Cu, Hg, Ni, Pb and Zn belongs to none pollution, comprehensive pollution level is clean level. In trunk roads, elements As, Cd, Cr, Cu, Ni, Bp and Zn belong to light pollution, only Hg belongs to serious pollution, comprehensive pollution level is light level. In parks district, most elements belong to light pollution, few places belong to medium pollution, comprehensive pollution level is clean level.

REASON ANALYSIS OF HEAVY METALS POLLUTION

This study presents five different environmental area of a city, in consist of living areas, industrial areas, mountain areas, trunk roads and parks district, through the analysis of question 1, we get contaminated degree of five areas is different and the content of eight kind of heavy metals are also different in each region. In order to analyze the main reason for the heavy metal pollution of the city, we analyze through cluster analysis method (Ma *et al*., 2008) and principal component analysis method (Liu and Guo, 2003), result that, for one part of the heavy metal pollution is serious and for the other part the heavy metal pollution is light, the serious part becomes the main cause of pollution.

Table 9: National evaluation standard for the first level

As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
15	0.2	90	35	0.15	40	35	100

Cluster analysis method: Clustering analysis (Wang and Sun, 2007) is an ideal multivariate statistical technique, mainly include the hierarchical clustering method and iterative clustering method. Clustering analysis is also called group analysis and point group analysis, is a multivariate statistical method to study the classification. For this problem, first of all, to standardize the raw data (part of data in appendix 2) to obtain the content analysis results of heavy metal elements in each area in Table 13.

In the table above, compare average value of the content of soil heavy metals element in living area with its corresponding background value of soil in China, we can find that As, Cd, Cr, Cu, Hg, Ni, Pb and Zn are all over the city soil background values. In contrast, elements Cr, Hg, Pb and Zn have larger coefficient of variation, all above 30%, Centered, elements Cd and Cu have centered coefficient of variation, As and Ni have smaller coefficient of variation Then we put the data of Table 9 into the SPSS software, using the hierarchical clustering method to obtain the hierarchical diagram in living area clustering in Fig. 11.

According to Fig. 1, divided Cd and Cu into the first category, Cr, Hg, Pb and Zn into the second category, As and Ni into the third category. The first two elements

Table 10: Single pollution index of the corresponding

I1	I2	I3	I4	I5	I6	I7	I8
0.101104	0.940625	0.173241	1.66015	0,218576	0.217962	0.173921	1.282046

Table 11: National evaluation standard for the second level

As	Cd	Cr	Cu	Hg	Ni	Pbs	Zn
25	0.6	300	100	0.5	60	300	250

Table 12: Single pollution index of the corresponding

I1	I2	I3	I4	I5	I6	I7	I8
0.101197	0.940989	0.173723	1.66136	0.218986	0.21885	0.174732	1.282843

Table 13: Results of the content of heavy metals of living area

Living areas	Sampling points	Background	Max	Min	Avg	Mid	Coefficient variation (%)
As	44	3.600	11.450	2.340	6.27	5.94	34.3
Cd	44	0.013	1.044	0.086	0.29	0.25	63.0
Cr	44	31.000	744.460	18.460	69.02	46.96	156.3
Cu	44	13.200	248.850	9.730	49.40	29.20	95.5
Hg	44	0.035	550.000	0.012	0.09	0.06	110.6
Ni	44	12.300	32.800	8.890	18.34	18.47	30.9
Pb	44	31.000	472.480	24.430	69.11	48.54	104.7
Zn	44	69.000	2893.470	43.370	237.01	120.92	187.2

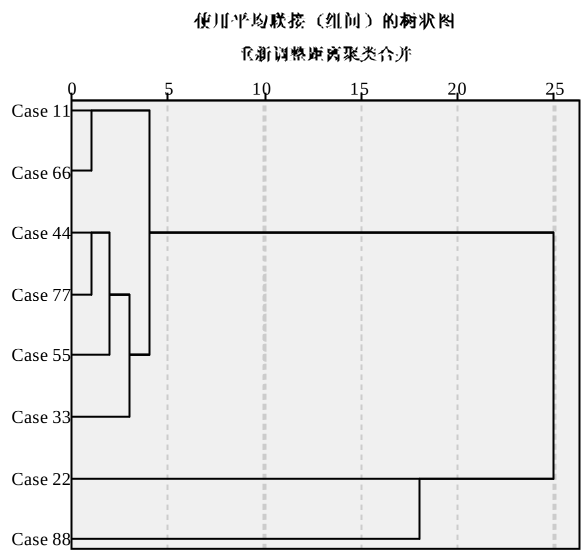

Fig. 11: Clustering results of living area

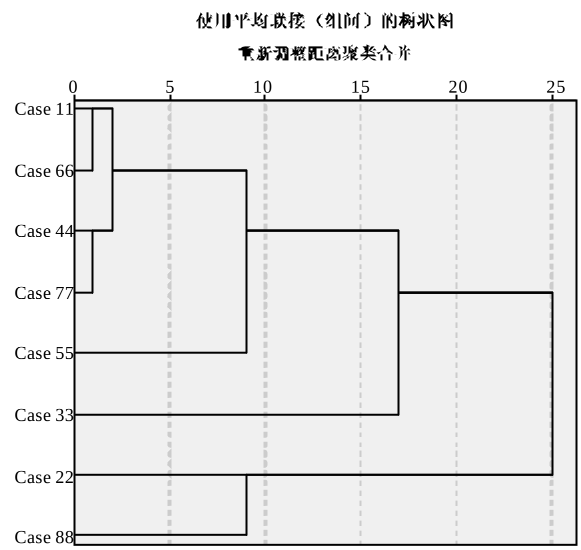

Fig. 12: Clustering results of industry area

content of the soil is relatively smaller than background element content, so it is a natural source that has less influence of personal factors; The second four elements content of the soil is relatively larger than background element content, so it is a natural source that has more influence of personal factors; The third two elements content of the soil is relatively larger than background element content, so, it has more influence of personal factors. We only list the living areas here, other regional analysis method is same as the above (specific data in the appendix 2), do not do too much description, other regional cluster pedigree chart in Fig. 12-15.

Principal component analysis: Principal component analysis (Li, 2010) is also called PCA, aimed at using the idea of dimension reduction, change the multiple indicators into a few more composite indicator. In the empirical research, in order to analyze the problem comprehensively and systematically, we must consider influence of many factors. These factors that involved in are generally referred as index, also known as a variable in the multivariate statistical analysis. For every variable in different extent reflects the research problem by certain information and the indexes have a certain correlation between each other, so the obtained statistical data reflect information to a certain extent of overlap. When we use the statistical method to study multivariate problems, too many variables can increase the amount of calculation and complexity of the problem analysis, it is hoped that in the process of quantitative analysis, less variable can be

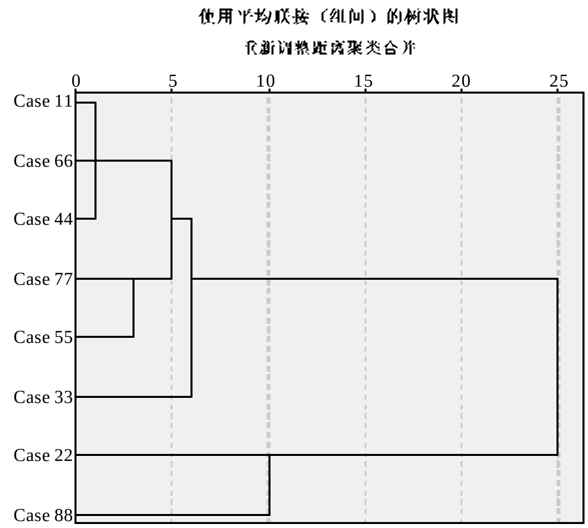

Fig. 13: Clustering hierarchical diagram of mountain area

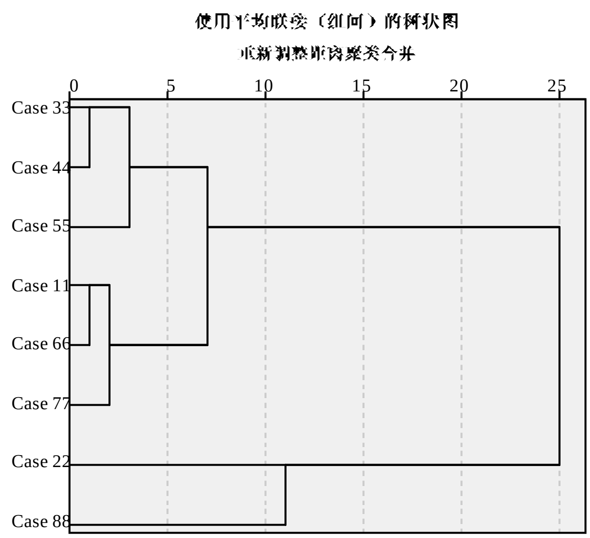

Fig. 14: Clustering hierarchical diagram of trunk roads

involved in, the we can get more information. First we lead the raw data of heavy metal elements in living areas into SPSS software to analyze the principal components, obtain the main component load matrix in Table 14 of various kinds of heavy metal elements in living areas in Table 15.

The principal of number extraction of principle component is the first m principle component that

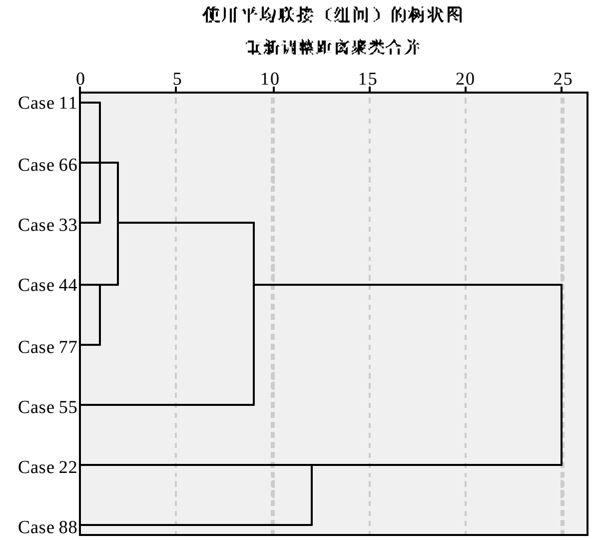

Fig. 15: Clustering hierarchical diagram of parks district

Table 14: Composition of the matrix of heavy metal elements in living areas

Composition of the matrix a

	Ingredients		
Heavy metals	1	2	3
As	0.67	-0.646	-0.007
Cd	0.783	0.170	-0.418
Cr	0.643	0.236	0.492
Cu	0.729	-0.246	0.025
Hg	0.493	0.128	-0.436
Ni	0.686	-0.251	0.524
Pb	0.803	0.111	-0.348
Zn	0.501	0.692	0.264

Extraction method: The main ingredients. a: Have extracted 3 ingredients

corresponding eigenvalues of component larger than 1, through Table 15, three principal components are extracted. Get the convenient of each index in three ingredients with the data in Table 14 divided by extract square of the number of principal components corresponding to eigenvalue, namely eigenvector A1, A2, A3 (Tan *et al*., 2006), result in the principal component expressions by multiplication of the feature vector by the standardized data:

$$F1 = A1\times ZX1 \quad (4)$$

$$F2 = A2\times ZX2 \quad (5)$$

$$F3 = A3\times ZX3 \quad (6)$$

Take the proportion of eigenvalue of each main component and the corresponding the total the sum of the

Table 15: Eigenvalues of heavy metal elements in living areas

Interpretation of the total variance

	Initial eigen value			Load extraction of sum of squares		
Ingredients	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
1	3.616	45.205	45.205	3.616	45.205	45.205
2	1.133	14.164	59.369	1.133	14.164	59.369
3	1.074	13.428	72.797	1.074	13.428	72.797
4	0.807	10.086	82.882			
5	0.524	6.544	89.427			
6	0.444	5.554	94.980			
7	0.236	2.954	97.934			
8	0.165	2.066	100.000			

Table 16: Composition of the matrix of heavy metal elements in industrial areas

Composition of the matrix a

	Ingredients	
Heavy metals	1	2
As	0.518	0.758
Cd	0.786	0.074
Cr	0.916	-0.206
Cu	0.868	-0.463
Hg	0.845	-0.459
Ni	0.767	0.421
Pb	0.858	0.049
Zn	0.859	0.188

Extraction method: the main ingredients. a: Have extracted 2 ingredients

Table 17: Composition of the matrix of heavy metal elements in mountain areas

Composition of the matrix a

	Ingredients		
Heavy metals	1	2	3
As	-0.009	0.668	0.478
Cd	0.601	-0.678	0.141
Cr	0.761	0.480	-0.365
Cu	0.517	0.469	0.615
Hg	0.324	-0.074	0.747
Ni	0.737	0.499	-0.409
Pb	0.605	-0.630	0.173
Zn	0.905	-0.173	-0.183

Extraction method: The main ingredients. a: Have extracted 3 ingredients

Table 18: Composition of the matrix of heavy metal elements in trunk roads

Composition of the matrix a

	Ingredients	
Heavy metals	1	2
As	0.235	-0.131
Cd	0.621	0.458
Cr	0.874	-0.319
Cu	0.906	-0.250
Hg	0.170	0.743
Ni	0.888	-0.320
Pb	0.703	0.477
Zn	0.643	0.115

Extraction method: The main ingredients. a: Have extracted 2 ingredients

eigenvalues that extract from as the weighting to calculate the principal component comprehensive model, use the corresponding coefficient of each index in the first principal component F1 multiplied by the first principal component contribution rate divided by the extraction of the F1 of the sum of the three principal component contribution rate and then add the second principal component corresponding coefficient multiplied by the percentage contribution of F2 and add the third principal component F3 corresponding coefficient multiplied by the percentage contribution, obtained the weight coefficient A of the comprehensive principal component F in each index (Ma *et al*., 2011). Descend order according to the weight coefficient A values, the main reason of pollution is the heavy metal elements that corresponding larger coefficient. Here only order the living areas, other regional analysis method are the same, we do not do too much description, principal components load matrix of various heavy metal elements of the other four in the region Table 16-20.

Table 19: Composition of the matrix of heavy metal elements in parks district

Composition of the matrix a

	Ingredients		
Heavy metals	1	2	3
As	0.636	-0.569	0.349
Cd	0.811	0.103	-0.232
Cr	0.809	-0.426	-0.003
Cu	0.679	0.457	-0.151
Hg	0.203	0.354	0.889
Ni	0.663	-0.622	0.012
Pb	0.782	0.544	0.097
Zn	0.798	0.286	-0.242

Extraction method: the main ingredients. a: Have extracted 3 ingredients

Evaluation results: For different regions in the city, we analyze the collected elements As, Cd, Cr, Cu, Hg, Ni, Pb and Zn of soil by clustering analysis and principal component analysis, clustering results of soil elements showed in Fig. 11-15, principal component results of soil elements showed in Table 20. Through the comparison of cluster analysis and principal component analysis, Principal component analysis is the better one.

Obtained by clustering and principal component analysis:

Table 20: Distribution of major pollution elements in each region

Living areas	Weight coefficient	Industrial areas	Weight coefficient	Mountain areas	Weight coefficient
Cr	0.34	Ni	0.34	Cu	0.35
Zn	0.34	Zn	0.33	As	0.23
Ni	0.27	As	0.31	Cr	0.23
Pb	0.22	Pb	0.31	Ni	0.22
Cd	0.21	Cd	0.29	Hg	0.21
Cu	0.20	Cr	0.29	Zn	0.17
Hg	0.11	Cu	0.23	Pb	0.06
As	0.10	Hg	0.22	Cd	0.04
Trunk roads	Weight coefficient		Parks district		Weight coefficient
Pb	0.38		Pb		0.36
Cd	0.34		Cu		0.27
Cu	0.29		Hg		0.27
Ni	0.27		Zn		0.26
Zn	0.27		Cd		0.23
Cr	0.26		Cr		0.16
Hg	0.23		As		0.14
As	0.06		Ni		0.08

- In living areas, the content of Zn and Cr elements was significantly higher than the national background value
- In industrial areas, the main pollution elements As, Cd, Cr, Cu, Hg, Ni, Pb and Zn
- In mountains areas, almost all elements are under the national background value, only element Cu is the main pollution element
- In trunk roads, Pb and Cd are higher than the background value, else elements are lower
- In parks district, Pb is the main heavy metals and Hg, Cu and Zn is the secondary heavy metal elements

DETERMINE SOURCE OF HEAVY METAL POLLUTION

Heavy metal pollutants in the soil move with the migration of soil water, heavy metal pollutants will be affected by the chemical and physical properties of the soil substrate and soil solute itself and other chemicals in the soil in the process of migration (Wu *et al*., 2009). The physical mechanism of soil solute transport mainly include convection, diffusion and mechanical dispersion. Due to the limited conditions in this study, select diffusion and gravity potential as its propagation characteristics, through the analysis of transmission characteristics, set up the partial differential model.

Analysis of transmission characteristics: Diffusion is caused by the thermal movement of solute molecules, the trend is migrate from high concentration to low concentration (Yang *et al*., 2007b), in order to achieve equal concentration, in a free aqueous solution, the solute diffusion follows the Fick's first law, expressed with mathematical expression:

$$J_d = -D_0 \frac{\partial c}{\partial z} \tag{7}$$

In the type, J_d is the solute in the free molecular diffusion of water flux, D_0 is the diffusion coefficient of solute molecules in free water, $\partial c/\partial z$ represents the solute concentration gradient, minus represents the direction of the concentration of solute molecules along the lower diffusion. In the soil solution, the soil solute diffusion also follow the Fick's first law, the mathematical expression:

$$J_{ds} = -\theta D_s \frac{\partial c}{\partial z} \tag{8}$$

In the type, J_{ds} is the diffusion of solute molecules in the soil in flux, D_s represents the solute molecular diffusion coefficient in the soil, either in saturated soil or in unsaturated soils, D_s are less than D_0, generally will expressed solute diffusion coefficient in the soil of only as the function of water content and has nothing to do with the concentration of the solute, its mathematical expression is commonly used empirical expression:

$$D_s = D_0 \tau \tag{9}$$

In the type, τ called tortuosity factor, is a dimensionless physical quantity, according to the research of Wagenet, for most of the soil, the range of 0.3-0.7. Soil heavy metal pollution of gravitational potential is due to the effect of gravity, its value is equal to move the unit weight of heavy metal pollutants from the soil heavy metal contaminant reference point to the research height of the point, work value of the heavy metal pollutants in the soil (Zhu and Wei, 2011). Gravitational potential selected location coordinates with the size of the height and direction of the coordinate system, generally in the process of research, often selected the surface of the earth's surface or groundwater as the origin of coordinates on and the direction of the axis can choose up or down according to the needs of calculation, if the research point height is z from the coordinates, the unit weight of soil heavy metal pollutants in the gravitational potential in unit length can be represented as:

$$\psi_g = \pm z \tag{10}$$

Type in: ψ_g is the gravitational potential for heavy metal pollutants.

Establishment of the partial differential model: Assuming that the environment medium (such as soil) at any point P(x, y, z), this point as a unit around, the side length o branch is 2dx, 2dy, 2dz, (Fig. 3-5) P point velocity v(x, y, z) in three directions respectively is u_x, u_y, u_z (Lin, 2011), then pollution material flux in the three directions:

$$\begin{aligned}\Delta m_x &= \Delta m_{1x} + \Delta m_{2x} + \Delta m_{3x} + \Delta m_{4x}\\ \Delta m_y &= \Delta m_{1y} + \Delta m_{2y} + \Delta m_{3y} + \Delta m_{4y}\\ \Delta m_z &= \Delta m_{1z} + \Delta m_{2z} + \Delta m_{3z} + \Delta m_{4z}\end{aligned} \tag{11}$$

Now the molecular diffusion coefficient, turbulent diffusion coefficient and dispersion effects spread into a dispersion term, namely:

$$\begin{aligned}E_x &= D_m + D_{1x} + D_{2x}\\ E_y &= D_m + D_{1y} + D_{2y}\\ E_z &= D_m + D_{1z} + D_{2z}\end{aligned} \tag{12}$$

E_x, E_y, E_y respect X, Y, Z direction of the dispersion coefficient. Mass flux of dispersion effect in the X direction are as follows:

$$E_{2x} = -E_x \frac{\partial c}{\partial x} \tag{13}$$

Quality flux of direction Y and Z:

$$E_{2y} = -E_y \frac{\partial c}{\partial y}, E_{2z} = -E_z \frac{\partial c}{\partial z} \tag{14}$$

Total mass flux of X, Y and Z:

$$F_x = F_{1x}+F_{2x}, F_y = F_{1y}+F_{2y}, F_z = F_{1z}+F_{2z} \tag{15}$$

Mass flux of the element get into from the X direction and get out:

$$4dydz\left(F_x - \frac{\partial Fx}{\partial x}dx\right) \tag{16}$$

Flux difference between the end faces (Qian, 1990):

$$-8dxdydz\frac{\partial F_x}{\partial x} \tag{17}$$

Similarly, flux difference in Y and Z direction:

$$-8dxdydz\frac{\partial F_y}{\partial y} - 8dxdydz\frac{\partial F_z}{\partial z} \tag{18}$$

In the element, variation of pollutant in infinitesimal time:

$$8dxdydz\frac{\partial C}{\partial t} \tag{19}$$

According to the law of conservation of mass :

$$\frac{\partial C}{\partial t} + \frac{\partial F_x}{\partial x} + \frac{\partial F_y}{\partial y} + \frac{\partial F_z}{\partial z} = 0 \tag{20}$$

Put relationship between type (3-l) to (3-4) type into type (3-5), result in:

$$\frac{\partial c}{\partial t} + u_x\frac{\partial c}{\partial x} + u_y\frac{\partial c}{\partial y} + u_z\frac{\partial c}{\partial z} = \frac{\partial}{\partial x}\left(E_x\frac{\partial c}{\partial x}\right) + \frac{\partial}{\partial y}\left(E_y\frac{\partial c}{\partial y}\right) + \frac{\partial}{\partial x}\left(E_z\frac{\partial c}{\partial z}\right) \tag{21}$$

That is:

$$\frac{\partial c}{\partial t} + \nabla(uc) = E\nabla^2 c$$

Considering the additional increase or decrease of the pollutant in the environment medium caused by physical (Zhu *et al*., 2012), chemical and biological, such as dispersing inflow and out flow along the river, the degradation, settlement, raise and adsorption of pollutants. Other pollution sources of pollutants incorporated from the air, absorb by vegetation and buildings of soil, the above mentioned can be combined as an additional source term S(x, y, z, c, t), is to:

$$\begin{aligned}&\frac{\partial c}{\partial t} + u_x\frac{\partial c}{\partial x} + u_y\frac{\partial c}{\partial y} + u_z\frac{\partial c}{\partial z} = \frac{\partial}{\partial x}\left(E_x\frac{\partial c}{\partial x}\right)\\ &+\frac{\partial}{\partial y}\left(E_y\frac{\partial c}{\partial y}\right) + \frac{\partial}{\partial x}\left(E_z\frac{\partial c}{\partial z}\right) + S(x, y, z, c, t)\end{aligned} \tag{22}$$

Simplified of the basic equations: Type (22) is the basic equation of environment pollutants migration and transformation, vortex with environmental fluid equation, so we can simulate pollutants migration and transformation process in various environmental media. Although type (19) is complete in theory, But if vortex with the fluid motion equations, it is necessary to master the parameters and model coefficient data of each space in different time and the data contains the extremely complex relationship between the space and time, therefore, it is very difficult to solve this equation. In the actual work, often do all kinds of simplify according to the predicted target, hydrological characteristics, the condition of medium or pollutants.

- **Zero dimensional model:** Under certain conditions, we can take the study of environmental media as a whole reactor. Within the space of environmental media, pollutants distribution is uniform, that is, there doesn't exist any one direction change of concentration, the pollutants enter in can instantly scattered to different parts, small lakes and box atmospheric is zero model
- **One dimensional model:** If the pollutants change along the X axis direction, uniform on the Y axis and Z axis, the model can be simplified as one dimensional. In uniform flow field, u_x and E_y can be used as a constant, written as:

$$\frac{\partial c}{\partial t}=\frac{\partial}{\partial x}\left(E_x\frac{\partial c}{\partial x}\right)-u_x\frac{\partial c}{\partial x}+S(x,y,z,c,t) \quad (23)$$

River water quality simulation and prediction can use one-dimensional model.

- **Two dimensional model:** The concentration of the pollutants when X and Y direction has changed, can be simplified as two dimensional model:

$$\frac{\partial c}{\partial t}=\frac{\partial}{\partial x}\left(E_x\frac{\partial c}{\partial x}\right)+\frac{\partial}{\partial y}\left(E_y\frac{\partial c}{\partial y}\right)-u_x\frac{\partial c}{\partial x}-u_y\frac{\partial c}{\partial y}+S(x,y,z,c,t) \quad (24)$$

Large rivers, estuaries, bays, shallow lake water quality simulation and prediction, can use two-dimensional model.

Solving the model: According to the data given in the question, this is a 3D model, solve the location of pollution sources on the 3D model, due to limited by conditions and data, we assume the biggest concentration place as pollution source, regardless of the element enrichment, we get the points of largest concentration according to the space distribution of heavy metal elements in the first question 1 of, the initial concentration of the biggest points out, According to the:

$$\begin{aligned}\frac{\partial c}{\partial t}&=\frac{\partial}{\partial x}\left(E_x\frac{\partial c}{\partial x}\right)+\frac{\partial}{\partial y}\left(E_y\frac{\partial c}{\partial y}\right)+\frac{\partial}{\partial z}\left(E_z\frac{\partial c}{\partial z}\right)\\&-u_x\frac{\partial c}{\partial x}-u_y\frac{\partial c}{\partial y}-u_z\frac{\partial c}{\partial z}+S(x,y,z,c,t)\end{aligned} \quad (25)$$

Under steady-state conditions of the point source $\partial C/\partial T = 0$, we can ignore the longitudinal diffusion and flow in the Y direction and Z direction, that is $E_x = 0$, $u_y = 0$, $u_z = 0$, The type can be simplified as:

$$u_x\frac{\partial C}{\partial x}=E_y\frac{\partial^2 C}{\partial y^2}+E_z\frac{\partial^2 C}{\partial z^2}+S(x,y,z,c,t) \quad (26)$$

This type of analytical solutions for:

$$C(x,y,z)=\frac{M}{4\pi x\sqrt{E_yE_z}}\exp\left[-\frac{u_x}{4x}\left(\frac{y^2}{E_y}+\frac{z^2}{E_z}\right)\right]\exp\left(-\frac{Kx}{u_x}\right) \quad (27)$$

Evaluation results: Then programming the 319 sampling points (part data in appendix) with MATLAB and solve the greatest concentration, obtained as follows: As(4400,7400,8), Cd(4500,1110,6), Cr(3400,5910,4), Cu(2400,3600), Hg(2600,2350,22), Ni (3200,5900,4), Pb (2000,3300,7), Zn (13600,9600,18), unit is m.

CONCLUSION

For the first question, the national evaluation standard is the second level, to analyze the error, now we use the first and third level to calculate (Zhou *et al*., 2012) and analyze the single pollution index in question 1 whether it's reasonable, then, we analyze the error in the first area as an example, other areas are the same to the first. This process is presented in Table 9-12.

Analyze relative error the two single pollution index and the solution on the calculated values, we find the results are less than 0.1%, it can be concluded that the error of question 1 in an acceptable range.

For the second question, There are a lot of road in living area, on both sides of the road were the burning of leaded gasoline and dust of tire wear will increase elements Zn and Cr in soil and because of human activities are frequent in living areas, supplies discarded as waste in daily life can also lead to the increase of these three elements. The "three wastes" emissions and metal smelting lead to the high content of those elements. Due to the mountains far away from urban and industrial pollution sources, only part of the metal mine mining can lead to leakage of some metal elements. In trunk roads, the main reason of pollution is caused by motor vehicle exhaust emission, it also significantly cause the soil heavy metal pollution of road on both sides, car petrol, engine, tires, lubricating oil and gold plated parts, that all can burn or wear and tear and release Hg and Zn elements. In parks district, the use of fertilizers will be different degree of influence of heavy metal pollution in parks district and groundwater irrigation and plastic film can increase the soil content of elements Cu and Zn. It is not difficult to find different degree of pollution of element Cd in each region, this is because the Cd is mainly stored in the form of zinc cadmium sulfide ore, lead-zinc and copper in zinc, cadmium mainly comes from zinc ore, lead smelting, alloy, electroplating, chemical plant emissions of waste water, industrial solid waste dumps, garbage infiltration containing waste batteries, sewage sludge as fertilizer and excessive or inappropriate use of chemical fertilizer and pesticide and so on.

We analyze the stability according to the problems, when all the raw data elements density unchanged in addition to Ni, the Ni density change in (-4, -2, 0, 2, 4), then observe the changes of overall weight coefficient. Here we take living areas as an example.

- **Ni change:** We assume that in living areas all of the elements is unchanged in addition to Ni and Ni values increased a.Here is different value a, the value of F1 Table 21
- **HG change:** We assume that in living areas all of the elements is unchanged in addition to Hg and Hg values increased a. Here is different value a, the value of F2 Table 22

When small changes in concentration of heavy metal elements, F1, F2 change is small, Comprehensive to get the stability of the model is very high, its composition coefficient does not do too big change through the change with heavy metal elements, so the scheme is suitable for the finishing of concentration.

Overall: Areas are more serious pollution when industrialization degree higher, urban area is higher than that of suburban and rural, surface is higher than that of underground, heavy metals accumulate more when the pollution time longer, the atmospheric media of soil heavy metal pollution in soil can be added strong, heavy metal content is higher when curing degree higher.

For the third question, There are advantages and disadvantages of models in question 3:

Advantages:

- Transmission characteristics that the model select are chosen according to the conditions the topic given, the movement of heavy metals in the soil can be appropriate explained

Table 21: Values of F1 in stability analysis

a	-4	-2	0	+2	+4
As	0.670	0.670	0.669	0.671	0.672
Cd	0.782	0.783	0.784	0.783	0.782
Cr	0.643	0.643	0.643	0.643	0.643
Cu	0.729	0.729	0.729	0.728	0.728
Hg	0.491	0.493	0.492	0.491	0.493
Ni	0.684	0.686	0.686	0.685	0.686
Pb	0.802	0.803	0.803	0.802	0.803
Zn	0.502	0.501	0.501	0.503	0.501

Table 22: Values of F2 in stability analysis

a	-2	-1	0	1	2
As	-0.646	-0.645	-0.646	-0.646	-0.647
Cd	0.170	0.172	0.171	0.170	0.170
Cr	0.236	0.236	0.234	0.236	0.235
Cu	-0.246	-0.245	-0.246	-0.246	-0.246
Hg	0.129	0.128	0.130	0.128	0.128
Ni	-0.251	-0.251	-0.253	-0.251	-0.253
Pb	0.113	0.111	0.112	0.111	0.111
Zn	0.692	0.692	0.691	0.692	0.692

- Corresponding to the three dimensional partial, changes of the concentration in each direction can accurately calculate
- In order to ensure the accuracy of the results, plenty of available data is used in the operation and process data in MATLAB, ensure the accuracy and reduces the amount of computation

Disadvantages: Metal contaminants in soils is related to many factors, but we only selected two, at this point will produce deviation with the actual deviation.

In order to research evolution model of city geology environment better, through information query related to the city geological environment, geological environment is a kind of natural environment, the environment system composed of lithosphere, hydrosphere and atmosphere. Therefore, we should also collect heavy metal pollution elements in the lithosphere, atmosphere and hydrosphere with the distribution map of time, considering the effect of a number of other factors, we establish the N dimensional partial differential equations, in order to get evolution model. In order to determine the position of pollution source, First of all, we find the point according to the features of pollution source, then according to the 3D graphics of concentration distribution of each sampling points to solve maximum concentration, in solving the most value problems on a curved surface of 3D graphics, we will get the most value by establish and solve the partial differential equations.

ACKNOWLEDGMENTS

We would like to thank the anonymous reviewers for their valuable comments. This program is supported by Scientific Research Program Funded by Shaanxi

Provincial Education Department (Program No. 2013JK1139) and Supported by China Postdoctoral Science Foundation (No. 2013M542370). The paper is partially supported by Natural Science Basic Research

Appendix 1: Due to huge volume data, we provide only part of the original data

x (m)	y (m)	Altitude z (m)	Function area	As (μg g^{-1})	Cd (ng g^{-1})	Cr (μg g^{-1})	Cu (μg g^{-1})	Hg (ng g^{-1})	Ni (μg g^{-1})	Pb (μg g^{-1})	Zn (μg g^{-1})
74	781	5	4	7.84	153.80	44.31	20.56	266.00	18.20	35.38	72.35
1373	731	11	4	5.93	146.20	45.05	22.51	86.00	17.20	36.18	94.59
1321	1791	28	4	4.90	439.20	29.07	64.56	109.00	10.60	74.32	218.37
0	1787	4	2	6.56	223.90	40.08	25.17	950.00	15.40	32.28	117.35
1049	2127	12	4	6.35	525.20	59.35	117.53	800.00	20.20	169.96	726.02
1647	2728	6	2	14.08	1092.90	67.96	308.61	1040.00	28.20	434.80	966.73
2883	3617	15	4	8.94	269.80	95.83	44.81	121.00	17.80	62.91	166.73
2383	3692	7	2	9.62	1066.20	285.58	2528.40	13500.00	41.70	381.64	1417.80
2708	2295	22	4	7.41	1123.90	88.17	151.64	16000.00	25.80	172.36	926.84
2933	1767	7	4	8.72	267.10	65.56	29.65	63.00	21.70	36.94	100.41
4233	895	6	5	5.93	201.40	45.19	24.90	259.00	14.60	35.88	102.65
5101	4080	13	1	8.23	756.40	42.73	87.52	63.00	19.26	88.74	184.69
5438	3994	10	2	9.35	407.50	55.54	61.83	112.00	24.05	66.82	208.27
5382	3012	50	1	8.90	307.30	54.39	57.21	326.00	25.72	131.93	256.94
5314	2060	40	4	3.77	242.10	30.93	32.13	28.00	11.56	50.60	144.69
5503	1127	6	1	5.41	178.90	29.54	23.73	52.00	9.89	49.84	118.88
5636	133	17	1	7.78	315.50	49.76	28.03	550.00	18.95	45.73	109.29
6605	374	6	1	5.62	134.60	25.33	19.10	45.00	11.66	40.50	87.14
7093	1381	45	4	5.41	235.60	36.88	48.80	43.00	14.06	53.61	213.47
7100	2449	89	4	4.58	203.80	39.03	24.18	87.00	16.66	53.09	138.88
6837	3490	28	4	6.91	568.50	54.59	113.46	264.00	23.22	82.40	399.90
7906	3978	22	4	5.00	506.50	59.45	70.71	202.00	26.13	78.01	334.39
8045	3052	39	4	5.62	880.00	78.29	121.12	293.00	25.61	171.14	540.00
14318	13569	30	5	8.23	121.30	43.29	31.63	86.00	11.40	33.21	46.86
10352	17133	31	5	10.74	479.20	96.28	29.23	98.00	25.30	80.36	112.35
9095	16414	29	5	11.68	870.50	70.84	35.17	302.00	29.10	78.15	435.44
10510	15314	19	5	7.34	279.00	51.25	27.95	44.00	22.50	51.20	117.66
13954	5615	61	5	6.05	162.00	36.22	17.91	35.00	14.20	36.41	61.02
10142	1662	8	5	5.41	907.00	43.08	36.48	10.00	14.50	41.02	121.20
17765	3561	8	5	6.26	132.90	42.59	16.58	27.00	16.20	35.52	63.31
6924	5696	7	5	6.47	197.00	38.18	21.09	64.00	18.60	40.18	168.05
4678	3765	40	5	6.47	100.70	36.19	13.31	42.00	11.50	34.34	56.23
6182	2005	25	5	4.79	119.10	35.76	19.71	44.00	9.90	39.66	67.06
5985	2567	44	4	7.56	63.50	33.65	21.90	60.00	12.50	41.29	60.50
7653	1952	48	5	9.35	156.00	57.36	31.06	59.00	25.80	51.03	95.90

Appendix 2:

	Sampling points	Background value	Maxium value	Minium value	Average value	Medium value	Coefficient variation (%)
Industrial areas							
As	36	3.600	21.87	1.61	7.25	6.52	58.5
Cd	36	130.000	1092.90	114.50	393.11	351.65	60.4
Cr	36	31.000	285.58	15.40	53.41	41.36	82.4
Cu	36	13.200	2528.48	12.70	127.54	41.02	325.4
Hg	36	0.035	13500.00	0.01	0.64	0.10	349.4
Ni	36	12.300	41.70	4.27	19.81	18.10	42.2
Pb	36	31.000	434.80	31.24	93.04	69.05	91.8
Zn	36	69.000	1626.02	56.33	277.93	176.79	126.2
Mountain areas							
As	66	3.600	10.99	1.77	4.04	3.54	44.5
Cd	66	130.000	407.60	40.00	152.32	130.25	51.5
Cr	66	31.000	137.34	16.20	38.96	30.93	63.1
Cu	66	13.200	69.06	2.29	17.32	14.69	62.0
Hg	66	0.035	206.79	0.01	0.04	0.04	68.0
Ni	66	12.300	74.03	5.51	15.45	12.40	67.5
Pb	66	31.000	113.84	19.68	36.56	29.97	48.5
Zn	66	69.000	229.80	32.86	73.29	65.66	42.2
Trunk roads							
As	138	3.600	30.13	1.61	5.71	5.36	176.3
Cd	138	130.000	1619.80	50.10	360.01	304.65	147.9
Cr	138	31.000	920.84	15.32	58.05	44.02	71.1
Cu	138	13.200	1364.85	12.34	62.21	41.06	51.7
Hg	138	0.035	16000.00	0.01	0.45	0.05	20.5
Ni	138	12.300	142.50	6.19	17.62	16.63	149.5
Pb	138	31.000	181.48	22.01	63.53	58.42	195.3
Zn	138	69.000	3760.82	40.92	242.85	156.61	63.1

Appendix 2: Continue

	Sampling points	Background value	Maxium value	Minium value	Average value	Medium value	Coefficient variation (%)
Parks district							
As	35	3.600	11.68	2.77	6.26	6.26	32.3
Cd	35	130.000	1024.90	97.20	280.54	280.54	84.1
Cr	35	31.000	96.28	16.31	43.64	43.64	34.0
Cu	35	13.200	143.31	9.04	30.19	30.19	75.1
Hg	35	0.035	1339.29	0.01	0.11	0.12	195.0
Ni	35	12.300	29.10	7.60	15.29	15.29	32.5
Pb	35	31.000	227.40	26.89	60.71	60.71	75.5
Zn	35	69	1389.39	37.14	154.24	154.24	149.7

Plan in Shaanxi Province of China (Program No. 2012JM8047). And this project is also supported by NSFC Grant (Program No. 11226173 and 61102163). This study is also supported by Scientific Research Program Funded by Xi'an University of Science and Technology (Program No. 201139). This job is also supported by Science and Technology Project of Xi'an (CX1262⑨). Shaanxi Provincial Natural Science Basic Research Program (2009JQ1010) Shaanxi Provincial Department of Education Science Research Program (2010JK702) Xi'an University of Technology PhD project started (104-210901).

REFERENCES

Li, Y., 2012. Analysis of city surface soil heavy metal pollution. Sci. Technol. Eng., 12: 2772-2774.

Li, Z., 2010. The improved analytic hierarchy process and the ideal solution sorting method combined with the application in the evaluation of heavy metal pollution. China Health Stat., 27: 166-169.

Lin, Y., 2011. Rock evaluation forms and pollution of soil heavy metals. Mineral Quanzhou, 31: 115-120.

Liu, T. and S. Guo, 2003. Soil heavy metal content of sewage irrigation for farmland in shenyang. Influence. Environ., 29: 51-52.

Ma, J. and C. Li and Y. Chen, 2011. Influence of heavy metal pollution in soil by land use and economic growth to the city-example of Kaifeng. J. Soil Sci., 48: 743-750.

Ma, L., X. Yang and C. Tong, 2008. Element geochemical characteristics of heavy metals in sediments HunHe basin in Liaoning province. J. Test., 27: 184-188.

Qian, S.D., 1990. Operations Research. Tsinghua University press, Beijing, China.

Tan, M., J. Chen, F. Xu, H. Zheng and X. Zhang, 2006. Heavy metal pollution of soil space prediction theory based on fuzzy set. J. Soil, 43: 389-396.

Wang, G. and L. Sun, 2007. Survey and evaluation of soil heavy metal pollution in east Gao sewage irrigation area of Inner Mongolia. J. Shanxi Sci. Technol., 22: 115-116.

Wu, C., J. Wu, Y. Luo, H. Zhang, Y. Teng, J. Song and L. Wu, 2009. The definition of the range of heavy metal pollution in soil and uncertainty analysis. J. Soil Sci., 46: 1006-1012.

Xu, S., S. Guo and X. Hu, 2007. Analysis of heavy metal pollution evaluation and speciation of cadmium in Shenyang Zhang Shi irrigation. J. Applied Ecol., 19: 2144-2148.

Yang, J., C. Wang, B. Li, H. Li, X. He, 2007a. Prediction of soil heavy metal pollution in soil of the edge of the city base on BP neural network: Example of chengdu plain based on Cd. J. Soil, 44: 430-436.

Yang, J., L. Sun and X. Yang, 2007b. Pollution assessment of farmland soil heavy metal along xi river in Shenyang. Agric. J. Environ. Sci., 26: 1933-1936.

Yue, X. and N. Wang, 2012. Analysis of urban topsoil heavy metal pollution. Innovat. Appl. Sci. Technol., 33: 116-117.

Zhou, M., C. Chen and H. Wang, 2012. Autumn in Shanghai typical atmospheric particulate matter in the process of polluting chemical composition characteristics. J. Environ. Sci., 32: 81-92.

Zhu, D. and M. Wei, 2011. Mathematical Modeling Method: Guidance and Case Analysis. Zhejiang University Press, Hangzhou.

Zhu, Z., X. Fan and H. Ling, 2012. Analysis of city surface soil heavy metal pollution. Qual. Goods, 2: 271-272.