Quality Comprehensive Assessment on Heavy Metal Contamination of Urban Soil Geological Environment

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ABSTRACT

The urban soil geological environment has been seriously heavy metal polluted by the frequent human activities and the influence of the compact industrial, transportation. In this paper, we made urban soil geology environment investigation, analyzing the As, Cd, Hg, Cr, Cu, zinc, Ni, Pb and so on eight kinds of heavy metal elements in the living area of the city, industrial area, mountainous area, the trunk road area and park green areas. As for the regional distribution, we firstly use the geological accumulation index of single factor pollution assessment of heavy metals in different area, reuse in NEIMEILUO the comprehensive pollution index of the regional comprehensive evaluation of heavy metal pollution degree, and finally made use of principal component analysis method to analyze the main causes of heavy metal pollution for providing the reference basis so as to reduce the effects of heavy metal soil geological environment of cities.

KEYWORDS: Soil geological environment; Heavy metals; Geological accumulation index; NEIMEILUO comprehensive pollution index

INTRODUCTION

With the rapid development of urban economy and urban population continues to increase, the influence of human activities on the urban environment quality has become more and more prominent. Frequent human activities and the influence of the compact industrial, transportation, urban soil has been caused serious heavy metal pollution. The research shows that heavy metals in urban soil can enter human body by swallowing, inhalation and skin absorb which directly does harm to the health of people especially for children, which also does through contaminated food indirectly affect the urban environment, atmosphere and water environment quality and the human body health [1-5]. Heavy metal is a kind of potentially harmful pollutants in soil environment. They are generally not easily with water leaching in the soil environment, cannot be decomposed by the microbes. On the contrary, the enrichment of heavy metals in soil environment can go into greater toxicity of methyl compounds. More seriously, the heavy metals in soil with concealment, early in its cumulative poisoning effect are not obvious, therefore not easy to be easily perceptible or attention, but once when its toxic shows, they will be difficult to eliminate.

Therefore, Verification for urban soil anomaly caused by heavy metal pollution and geological environment has increasingly become the focus of attention. Meanwhile, the application for verifying the data to carry out the urban soil [6-9] geological environmental quality evaluation, the study of human activities, especially the evolution of the urban geological environment model, under the influence of heavy metals are more important.

URBAN ZONING AND SPATIAL DISTRIBUTION OF HEAVY METALS SOIL

For the urban soil geology environment investigation of a certain city, according to the function of the city to city, we divided the city into a living area and industrial area, mountainous area, the trunk road area and park green areas, such as notes for class 1 area respectively, 2 class area,..., 5 classes, different regional environment affected by human activities, especially heavy metal pollution degree. The examined urban area is divided into spacing area network grid, about 1 km per square kilometer in a sampling point on the surface soil sampling (0 ~ 10 cm depth), number, and we use GPS to record the location of sampling points. Application of special equipment testing analysis for each sample of As, Cd, Hg, Cr, Cu, zinc, Ni, Pb, etc. 8 kinds of heavy metal element concentration data. According to the distance of 2 km away from people and industrial activities in the natural area sampling, we use as for the city of heavy metals in surface soil element background values, collected 319 samples in the area of five points. So point coordinates of two-dimensional profiles are shown in figure 1 below (coordinate unit: m), three-dimensional map are shown in figure 2 below (coordinate unit: m)

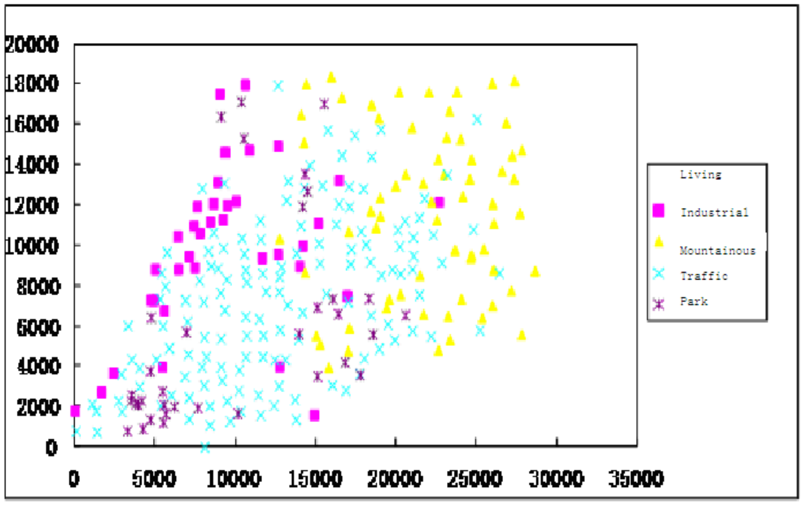


Figure 1: sample points 2d scatter plot

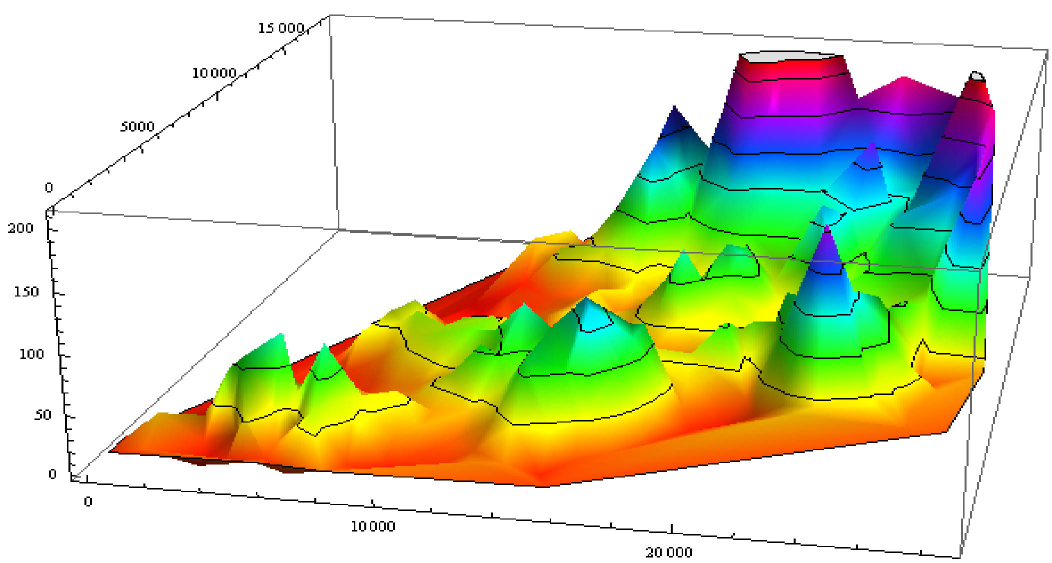


Figure 2: sample points 3d scatter plot

Through the scatter distribution of sampling points , there is a lot of net grid area that is no sampling data, so the need to use the existing sample data of unknown data.

By the known sample point data, on the basis of Kriging interpolation method, we got the basic idea of the spatial correlation of sample points and the weight of each sample points, but the unknown point of heavy metal concentration condition. And then we need to divide into five pollution levels of eight heavy metals concentration .For the research of heavy metal pollution, we need for eight kinds of heavy metal concentration in the further processing, thus get comprehensive reflection of heavy metal pollution index, using the index evaluation of various functional areas affected by heavy metal pollution.

For the unknown point estimates, we make use of the situation of the heavy metal concentration in the first place to determine the distance between the sample and the relationship between the concentration of heavy metals, and use half the coefficient of variation function space (semivarigram) to describe the concentrations of heavy metals in different directions, different distance variation trend of the tool.

（1） Calculating the distance between the different half mutation function value

According to the scatter plot , we can calculate, among 319 sample points, the distance between two points, and the same distance from the point of consolidation. We propose a heavy metal concentration $Z(x_i)$ in the density of points x_i , and distance h for all the points of concentration of heavy metals $Z(x_i+h)$, so half the variation function in their space

$$\gamma(h)=\frac{1}{2n}\sum_{i=1}^{n}[Z(x_i+h)-Z(x_i)]^2 \tag{1}$$

（2） Variance curve fitting functions

According to the above change $\gamma(h)$ shows linear trend, using the straight-line function fitting, for its form

$$y=m_1x+m_2 \tag{2}$$

We use h as the independent variables, $\gamma(h)$ as the dependent variable, the variance function fitting available variance curve fitting functions.

（3） Kriging interpolation estimation and sample weight calculation

Estimating of the unknown point x_i density of heavy metals, the available information of known sample points, using (2) interpolation

$$Z^*(x_0)=\sum_{i=1}^{n}\lambda_i Z(x_i) \tag{3}$$

In equation, x_0 is unknown point, x_i is known point, λ_i is weight coefficient, Its value is solved by (4).

$$\beta = [A^T A]^{-1} A^T R \tag{4}$$

Among them, $\beta = (\lambda_1, \lambda_2, ..., \lambda_n)$, $R = (\gamma_{10,} \gamma_{20,} ..., \gamma_{n0,})^T$

Matrix R is according to the fitting model, calculate the sample points and space half the variation of the unknown function value and composition. Matrix A is also the fitting model (2), and the space between any two points i, j and a half variation function value γ_{ij} and composition.

$$A = \begin{bmatrix} 0 & \gamma_{12} & ... & \gamma_{1n} & 1 \\ \gamma_{21} & 0 & ... & \gamma_{2n} & 1 \\ & \gamma_{n1} & \gamma_{n2} & ... & 0 \\ 1 & 1 & ... & 1 & 0 \end{bmatrix}$$

According to the result of interpolation, we get space continuous data, through ArcGIS software to make eight kinds of heavy metal elements in the urban spatial distribution, spatial distribution of eight heavy metals as shown in figure 3-10

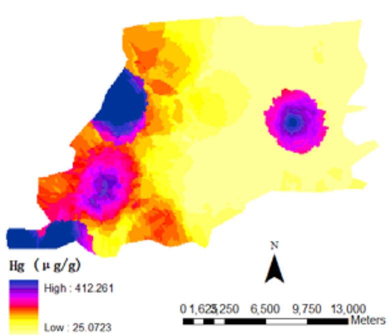


Figure 3: Hg spatial distribution

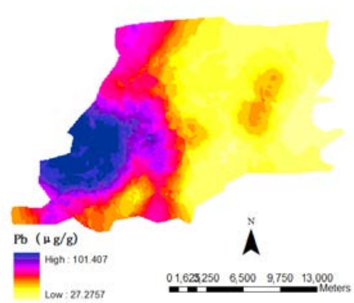
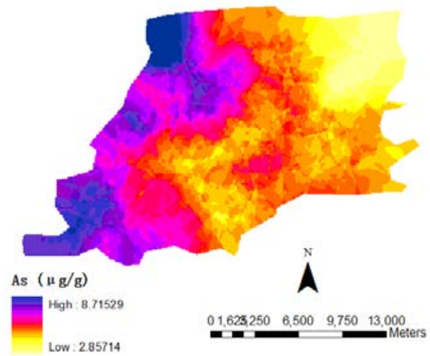


Figure 4: Pb spatial distribution



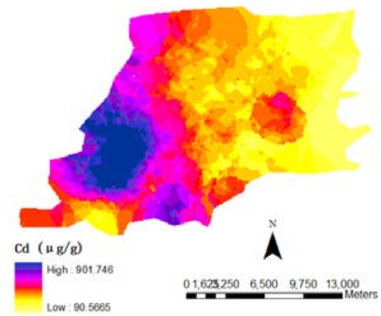
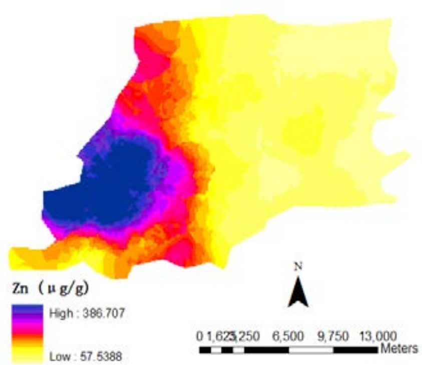


Figure 5: Cd spatial distribution **Figure 6:** As spatial distribution



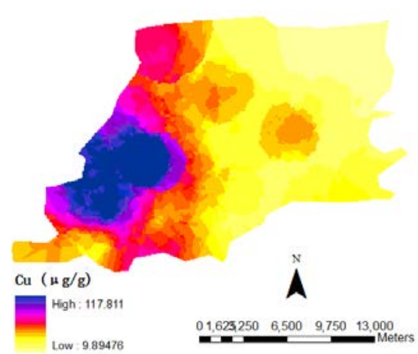
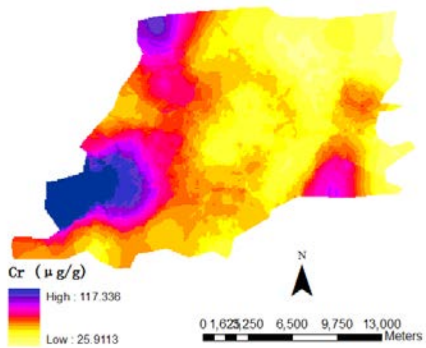


Figure 7: Zn spatial distribution **Figure 8:** Cu spatial distribution



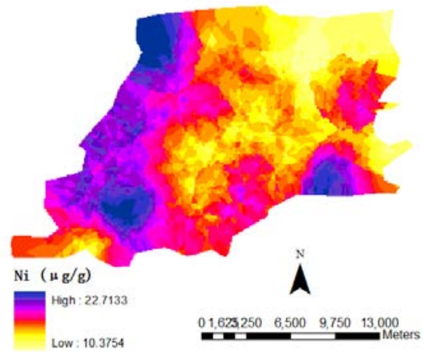


Figure 9: Cr spatial distribution **Figure 10:** Ni spatial distribution

We take the soil background values statistic average plus two times the standard deviation as a standard evaluation classification, so we can determine the eight heavy metals pollution level as shown in Table 1:

Table 1: Eight kinds of heavy metals pollution level

	No pollution	Light pollution	Moderate pollution	Strong pollution	Heavy pollution
As	0~3.6	3.6~5.4	5.4~7.2	7.2~9	>9
Cd	0~130	130~190	190~250	250~310	>310
Cr	0~31	31~49	49~67	67~85	>85
Cu	0~13.2	13.2~20.4	20.4~27.6	27.6~34.8	>34.8
Hg	0~35	35~51	51~67	67~83	>83
Ni	0~12.3	12.3~19.9	19.9~27.5	27.5~35.1	>35.1
Pb	0~31	31~43	43~55	55~67	>67
Zn	0~69	69~87	87~99	99~111	>111

3. By using geological accumulation index for evaluation of single factor pollution degree of heavy metals in different regions

Geological accumulation index [13-15] is commonly known as Muller index, we not only consider the natural background values of the impact of the geological process, but also fully pay attention to the impact of human activities on the heavy metal pollution. Therefore, the index changes not only reflect the nature of the heavy metal distribution characteristics, and it can distinguish the environmental impact of human activities, which is an important parameter to distinguish the human activity influence. The expression formula is as follows:

$$I_{ij} = \log_2 \frac{\overline{C_{ij}}}{kB_j} \qquad (5)$$

Among them, k is coefficient in consideration of differences of rocks around causing the change of the background value , which take average value 1.5, to stand for sedimentary characteristics, rock geological and other effects, $\overline{C_{ij}}\left(i=1,2,\ldots,5;\ j=1,2,\ldots,8\right)$ is j kind of heavy metal element concentration measured average.

To process in the first place, we get each partition 8 kinds of the concentration of heavy metal element and then get the district i average of the kind j of heavy metal element concentration measurement $\overline{C_{ij}}$, this generation becomes into the formula (1) , thus we get each area all kinds of heavy metals pollution index Table 2 as follows:

Table 2: District of heavy metal element value I

	As	*Cd*	*Cr*	*Cu*	*Hg*	*Ni*	*Pb*	*Zn*
Living quarters	0.2156	0.5724	0.5698	1.3191	0.8255	−0.0084	0.5716	1.1953
Industrial zone	0.4253	1.0115	0.1999	2.6873	3.6130	0.1027	1.0006	1.4251
Mountain area	−0.4171	−0.3564	−0.2552	−0.1933	−0.3582	−0.2557	−0.3471	−0.4979
Traffic zones	0.0800	0.8846	0.3202	1.6518	3.0893	−0.0666	0.4503	1.2305
Park green area	0.2141	0.5247	−0.0917	0.6087	1.1311	−0.2711	0.3847	0.5756

4. By Nemerow comprehensive pollution index to evaluate the regional comprehensive heavy metal pollution

Nemerow comprehensive pollution index [16-18] is a kind of extreme value type or highlight the maximum weight of give attention to two or more things factor index of environment quality. Special consideration is the number of the most polluted factor, Nemerow environmental quality index in the process of weight avoids the influence of subjective factors in the weight coefficient, which is a kind of environmental quality index is still is widely applied. The basic calculation formula of Nemerow comprehensive pollution index is:

$$P_i = \left(\frac{I_{i\max}^2 + \left(\frac{1}{8} \sum_{j=1}^{8} I_{ij} \right)^2}{2} \right)^{\frac{1}{2}} \qquad (6)$$

In the equation, $I_{i\max}$ is the maximum in i area heavy metals pollution , $\frac{1}{8}\sum_{j=1}^{8} I_{ij}^2$ is in i district mean value of j kind of heavy metals pollution

Looking for the People's Republic of China environmental protection industry (HJ/T166-2004 standard of soil environmental monitoring technical specifications [19] .we get Nemerow comprehensive pollution index classification standard in the following Table 3

Table 3: The Nemerow comprehensive pollution index classification standard

Level	Nemerow comprehensive pollution index	Pollution level
1	$P \le 0.7$	Clean (SAFE)
2	$0.7 < P \le 1$	Slight clean (red line)
3	$1 < P < 2$	Light pollution
4	$2 < P \le 3$	Moderate pollution
5	$P > 3$	Heavy pollution

Within the various functional areas of heavy metals on average, the comprehensive pollution index in Table 4

Table 4: The Nemerow comprehensive pollution index in functional area

Functional area	Living quarters	Industrial zone	Mountain area	Traffic zones	Park green area
The Nemerow comprehensive pollution index	4.56	14.68	1.65	11.90	3.74

The highest Nemerow comprehensive index is 14.68 in industrial zone, showing that industrial zone of heavy metal pollution is most serious, the lowest Nemerow index is 1.68 in the mountains, which indicates the slightest explanation in the mountains of heavy metal pollution degree.

For more intuitively compared to heavy metals pollution in various functional areas, according to the environmental quality grading standard, when PI is less than 0.7, the pollution level for Ⅰ, there is no urban pollution.

Table 5: pollution classification

Pollution levels	I	II	III	IV	V	VI
Index range	<0.7	0.7~1	1~3	3~5	5~7	>7

According to classification of pollution level and the sample point, the Nemerow comprehensive pollution index, we can map out comprehensive pollution level of the city, using the image can be more intuitive image that shows the various functional areas in the city pollution levels, and through the images we obtain valuable information about heavy metal pollution control.

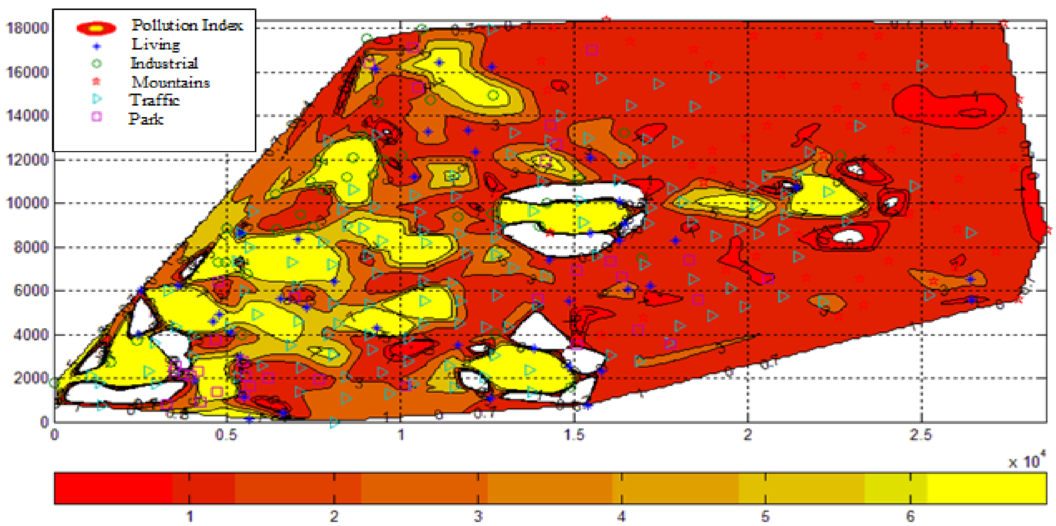


Figure 11: city comprehensive pollution map

By Nemerow comprehensive pollution index , we evaluate the pollution degree of heavy metals, From figure 11 overall we can see that the city pollution is more serious in the west and in most areas in the west of the city inside, the Nemerow comprehensive pollution index is more than 5, namely high pollution levels. But pollution in the eastern part of town is relatively minor, the Nemerow comprehensive pollution index IS in 0 ~ 1.5 range, belonging to non-pollution or light pollution areas. And a large number of eastern city is in mountain area, the west area is mostly in the industrial zone, the pollution degree of figure can be a revelation to us, that is by the urban greening we can solve the problem of heavy metal pollution in the city. From the perspective of green environment at the same time, the figure can provide valuable reference for the reasonable urban planning information.

5. The regional analysis of the causes of heavy metal pollution

Urban soil heavy metals come from soil parent material and human activities, a kind of pollution reasons are likely to make several kinds of heavy metal element content exceeds bid, so we calculate what kinds of heavy metal elements may be derived from the same pollution, thus we take a correlation coefficient to determine whether different sources of heavy metal element comes the same source. After the significance test, we use the principal component analysis [20-22] to analyze the contribution rate of different metal on this area, coupled with collected about the eight kinds of metal pollution sources, so as to make comprehensive analysis of the main causes of heavy metal pollution in different areas.

The establishment of the model and solution

By SPSS , we make standardization of eight kinds of metal elements concentration data in different functional areas and then constructs the five functional areas of soil heavy metal correlation coefficient matrix, correlation between the same source of metal, which can be judged whether the correlation of soil heavy metal pollution sources are the same. If there were significant positive correlation between heavy metal, its source could be the same, otherwise sources may be more than one. Districts of the correlation coefficient of soil heavy metals are shown in Table 6-10 below:

Table 6: The correlation coefficient of the living quarters of soil heavy metals

	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
As	1.000	0.381	0.238	0.531	0.293	0.605	0.450	-0.017
Cd		1.000	0.349	0.499	0.397	0.283	0.802	0.346
Cr			1.000	0.376	0.150	0.527	0.416	0.412
Cu				1.000	0.198	0.434	0.502	0.238
Hg					1.000	0.211	0.340	0.242
Ni						1.000	0.300	0.334
Pb							1.000	0.328
Zn								1.000

Table 7: The correlation coefficient of soil heavy metal in industrial zone

	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
As	1.000	−0.399	0.399	0.204	−0.198	0.593	0.105	−0.177
Cd		1.000	0.042	0.571	0.399	0.132	0.508	0.708
Cr			1.000	0.415	−0.258	0.571	0.515	0.259
Cu				1.000	0.400	0.589	0.560	0.625
Hg					1.000	−0.094	0.025	0.243
Ni						1.000	0.273	0.354
Pb							1.000	0.607
Zn								1.000

Table 8: The correlation coefficient of soil heavy metal in mountain

	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
As	1.000	−0.291	0.113	0.527	0.075	0.078	−0.205	−0.176
Cd		1.000	0.066	0.090	0.246	0.049	0.766	0.606
Cr			1.000	0.364	−0.006	0.945	0.107	0.627
Cu				1.000	0.505	0.358	0.122	0.252
Hg					1.000	−0.045	0.226	0.170

Ni						1.000	0.028	0.629
Pb							1.000	0.590
Zn								1.000

Table 9: The correlation coefficient of soil heavy metal in traffic zone

	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
As	1.000	0.121	0.139	0.092	−0.004	0.228	0.060	0.188
Cd		1.000	0.373	0.424	0.211	0.351	0.615	0.294
Cr			1.000	0.894	0.012	0.869	0.428	0.395
Cu				1.000	0.032	0.886	0.506	0.432
Hg					1.000	.040	0.266	0.118
Ni						1.000	0.396	0.503
Pb							1.000	0.482
Zn								1.000

Table 10: The correlation coefficient of soil heavy metal in green garden

	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
As	1.000	0.358	0.689	0.107	0.176	0.691	0.265	0.285
Cd		1.000	0.564	0.500	0.054	0.433	0.598	0.712
Cr			1.000	0.357	0.023	0.739	0.397	0.509
Cu				1.000	0.136	0.267	0.756	0.521
Hg					1.000	−0.048	0.389	0.063
Ni						1.000	0.168	0.298
Pb							1.000	0.748
Zn								1.000

From the correlative coefficient of the soil heavy metals in the living area was significantly correlation between Pb and Cd, the correlation coefficient is 0.802, which suggests that these two metal may have the same sources of pollution.

In the same way, we can get, in the industrial zone, zinc and Cd, Cu and zinc, zinc and significantly correlation between Pb, the correlation coefficient is 0.708, 0.625, 0.607 respectively. These four heavy metals may be the same source.

In the mountains, the correlation coefficient between Ni and Cr is 0.945 , which indicates these two elements are likely to from the same source.

In Traffic area, Cu and Cr, Ni and Cr, Ni and Cu two related, and the correlation coefficient is 0.894, 0.894, 0.869 respectively, which also shows that the three kinds of heavy metals have the same source.

In Park green areas, Ni and Cu, Pb and Cu and zinc and Cd, zinc and Pb the correlation coefficient are 0.739, 0.756, 0.712, 0.739 respectively, which have significant correlation and may be from the same sources of pollution.

The significance level $p < 0.05$ in five different area , the five areas meet with the conditions of the principal component analysis, so we can analyze the main heavy metal pollution element of the region.

Table 11: Functional areas principal component analysis results

Functional area	Principal Component one	Principal Component two	Principal Component three	Accumulative contribution rate
Living quarters	Pb、Cd 45.199%	Zn 14.165%	Ni 13.432%	72.797%
Industrial zone	Cu、Zn 42.045%	As 27.257%	Hg 12.535%	81.837%
Mountain area	Zn 38.022%	As、Cd 25.445%	Hg 19.362%	82.829%
Traffic zones	Cr、Cu、Ni 46.883%	Hg 16.084%		62.9675
Park green area	Cd、Cr、Pb、Zn 48.840%	Ni 20.182%	Hg 13.202%	82.225%

（Significant level $p < 0.05$）

Coupled with the eight heavy metals pollution source data and the results of correlation coefficient analysis, we can show that the main reason for the heavy metal pollution in different areas.

Table 12: Heavy metal pollution source

heavy metal	pollution reason
As	(1) The burning of coal can lead to different levels of arsenic pollution (2) Some development of non-ferrous metal smelting (3) Arsenic pesticide production and use, and the use of some industrial raw materials
Cd	(1) Electroplating, mining, smelting, dye, battery and chemical industrial waste water discharge (2) The pollution of the soil, mainly through two forms, one is the industrial waste gas of cadmium in the wind around diffusion, the natural sedimentation and accumulation in soil around the factories, another way is industrial wastewater containing cadmium irrigated farmland, making the soil polluted by cadmium (3) Type air pollution is mainly composed of industrial waste gases containing cadmium diffusion and natural sedimentation. The pollution of cadmium in water mainly from surface runoff and the industrial waste water (4) garbage
Cr	(1) Chromium is mainly used for metal processing, electroplating, leather and other industries (2) Industry waste water and exhaust gas emissions is main cause of the environment of chromium in human (3) Metallurgy, cement and other industries, as well as coal and oil burning gas, chromium containing particles state
Cu	The main pollution sources are copper and zinc mining and smelting, metal processing, machinery manufacturing, steel production, etc

Hg	(1) Water mercury pollution is caused by human activities, mainly from alkali, plastic, battery, electronics and other industrial waste water discharge (2) Automobile exhaust particulate matter
Ni	Nickel ore mining and smelting, alloy of copper production and processing The emission of smoke and ashes from combustion of coal, oil, Production process of nickel plating, crossing
Pb	(1) Lead pollution to the environment is made by smelting, industrial and mining enterprises and the use of lead products (2) Another Is caused by waste gas with lead from the cars (3) Garbage
Zn	(1) The main pollution sources are zinc mining, smelting, processing, machinery manufacturing, and galvanized, instruments and meters, which have the opportunity to synthesize and paper and other industrial emissions (2) Auto tire wear, and dust, smoke from the burning of coal containing zinc and compounds

Through data analysis, we first analyze the pollution cause of living quarters, not only high Pb and Cd correlation, and they all belonged to the first principal component, by the situation (living garbage heap corruption of heavy metals mainly Pb and Cd), living garbage is the main pollution reasons living quarters. And there are high content in the second principal component is zinc, the third principal component in high load is Ni, their contribution rate is 14.165% and 14.165% respectively, the tire and ground friction is an important way to produce zinc, Ni is the composition of automobile exhaust particulate matter, which indicates that traffic pollution is also the living quarters of important causes of pollution.

In industrial zone, the first principal component is Cu and zinc, contribution rate is 42.045%, and the correlation coefficient between them is 0.625, the second principal component is the As, contribution rate is 27.257%, the third principal component is Hg, contribution rate is 12.535%, From the analysis, industrial zone of heavy metal pollution is mainly metal smelting, machinery manufacturing, electronic industrial emissions of waste gas, waste water, waste residue and excessive mining operations.

In Mountains, the three main ingredients are zinc, As and Cd, Hg, the cumulative contribution rate was 82.829%, and the correlation between heavy metal analysis showed that the source of Ni and Cr are the same, so we mainly analyze the result of principal component, the main reason of the pollution comes from the various of mine exploitation and the diffusion and deposition of the waste gas and waste water.

In Traffic zone, the first principal component is Gr, Cu, Ni, contribution rate is 46.883%, and that the correlation coefficient between two are 0.894, 0.869, 0.886 respectively, so the three kinds of heavy metal pollution sources are the same. Hg is the second principal components accounted for 16.084%, which also is pollution from the automobile exhaust pollution. The results are different in practice, which also differ from what we forecast, which may be associated with the pattern of the city, and also may be the city industrial pollution is serious

In Park green areas, the first principal component is a Cd, Cr, Pb, zinc, the second principal component is Ni, the third principal component is Hg, the cumulative contribution rate of 82.225%. Ni, Cu, Pb and Cu and zinc and Cd, zinc, and Pb are significantly related, heavy metal pollution is coming from the main reason of the car traffic pollution, industrial waste gas diffusion and subsidence, and surface runoff is also an important reason of wastewater.

CONCLUSION

In this paper, we investigate the city of urban soil geology environment , and make analysis of the As, Cd, Hg, Cr, Cu, zinc, Ni, Pb and so on eight kinds of heavy metal elements in the living area of the city, industrial area, mountainous area, the trunk road area and park green areas. As regional distribution, we are firstly using the geological accumulation index of single factor pollution assessment of heavy metals in different area, and reuse in Nemerow comprehensive pollution index for the regional comprehensive evaluation of heavy metal pollution degree. Finally , we use principal component analysis to analyze the main causes of heavy metal pollution, to provide the reference basis for reducing the effects of heavy metal soil geological environment of cities.

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