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Contamination, Spatial Distribution and Source Analysis of Heavy Metals in Surface Soil of Anhui Chaohu Economic Development Zone, China

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Abstract: Anthropogenic activities may result in the accumulation of heavy metals in the soil, especially in economic development zones with frequent industrial activities. Therefore, the investigation and assessment of soil heavy metal pollution in economic development zones is one of the important measures for soil environmental management and sustainable development. This study used Nemero evaluation, Kriging interpolation, cluster analysis, and principal component analysis to investigate the contamination degree, spatial distribution, and origin of heavy metal in Anhui Chaohu Economic Development Zone (ACED), Anhui, East China. The result showed that different land use types can cause different levels and types of soil heavy metal pollution. The maximum concentrations of heavy metals in the study area all exceeded their background value but did not exceed the guide values. The highest average concentrations were found in Zn, followed by Cr and Ni. The concentrations of As in soils have the largest coefficient of variation (CV) at 38%. The concentration of heavy metals in different functional areas was varied, the areas with higher Ni, As, Cd, Zn, and Cr concentrations were mainly distributed in Hot Springs Resort (HSR), the relatively higher concentrations of Pb, Hg, and Cu were mainly distributed in Integrated Zone (IZ), while all heavy metal (except for Ni) have relatively higher content in the surface soil of Huashan Industrial Zone (HIZ). Origin analysis showed that soil As, Cd, and Zn in HSR surface soil were predominantly influenced by agricultural activities, while Ni and Cr were mainly controlled by parent material. Pb and Hg in IZ surface soil were predominantly originated from the vehicle and domestic exhaust, and Cu was mainly controlled by industrial pollutants. Industrial activity was the main source of soil heavy metals in HIZ. Although heavy metal in ACED surface soil did not reach pollution levels, the concentration of Cd, Hg, Pb, and Cu was significantly affected by anthropogenic activities, especially in HIZ, which the necessary attention of heavy metals needs to be given.

Keywords: soil contamination; industrial area; urban soil; pollution assessment; topsoil

1. Introduction

It is well known that the soil heavy metal pollution may lead to various diseases to humans through the food chain and suspended dust [1]. Therefore, heavy metal pollution in the soil has been a large concern for people. Heavy metals in soil mainly come from parent materials and anthropogenic activities [2–4]. However, in the past several decades, with the development of industrialization and urbanization, anthropogenic activities such as coal-burning, metallurgy, mining, vehicular emissions, and agricultural activities have become major contributors to the accumulation of heavy metals in soils [5–7]. As a result, soil heavy metal pollution has grown to be a major environmental problem in China, especially in the industrial and mining areas [8,9].

Urbanization and industrialization are often accompanied by changes in the types of land use, which increase the impact of human activities on the heavy metals in the soil, resulting in the accumulation and even pollution of heavy metals in the soil [10]. In China, the economic development zone plays an important role in the Chinese economy. In the past 40 years, countless economic development zones have been set up throughout the country. Until the end of 2018, 219 national economic development zones have been established. However, although economic development zones have brought economic progress, they have also brought various environmental problems such as air, water, and soil pollution [11]. Among them, the problem of soil heavy metal pollution in economic development zones has not received due attention for a long time in China [12,13].

In many cases, China's economic development zone is not just an industrial zone. It often contains multiple functional zones such as industry, residential, commerce, and so on. Therefore, the concentration of heavy metals in economic development zone soils can be influenced by many factors, such as domestic waste, industrial emissions, building materials, automobile exhaust, and parent materials [14–17]. Owing to the complexity of heavy metal pollution in economic development zones, the determination of heavy metal content, pollution status, spatial distribution, and origin has become very important for environmental protection and governance.

There are numerous studies on the contamination assessment, spatial distribution analysis, and source identification of soil heavy metal pollution [11,18,19]. The generally used method for the source identification of soil heavy metal pollution is multivariate statistics such as principal component analysis, cluster analysis, and person correlation analysis [20–22]. Kriging is also a typical method for obtaining maps of heavy metal spatial distribution and combined with multivariate statistics to aid in pollution assessment and source identification [23–25]. Moreover, the assessment of heavy metal pollution is also of serious concern. There are many methods for evaluating soil pollution. Among them, Nemero index, Geo-accumulation index, and Health Risk Assessment are widely used assessment methods [26,27].

In recent years, scholars have made great achievements in heavy metal pollution assessment and pollution source identification [28–30]. However, most research has focused on the industrial and mining sectors, and economic development zones with diverse land use types have received less attention. Due to the diversity of soil heavy metal pollution sources in economic development zones, heavy metal may have a different concentration, and spatial distribution characteristics. Therefore, analysis of the source, concentration and spatial distribution characteristics of heavy metal is one of the important prerequisites for controlling heavy metal pollution.

As a typical national economic development zone in eastern China, Anhui Chaohu's economic development zone (ACED) was established in 1995. However, the characteristics of soil heavy metals in ACED surface soil are still unknown. Since the development zone contains many metal processing enterprises, roads, and residential areas, the potential soil heavy metal pollution in ACED cannot be ignored. Therefore, the investigation of soil heavy metal in development zones has become essential. Consequently, the purpose of this study were: (1) Analyzing the content and spatial distribution of heavy metals in the surface soil of ACED; (2) determining the pollution degree and origin of heavy metals in ACED; (3) providing the basis for the prevention and control of soil heavy metal pollution in economic development zones in China.

2. Materials and Methods

2.1. Study Area

Anhui Chaohu economic development Zone (ACED) is one of the major economic development zones in Hefei, located in the middle of Anhui province (31.64° N, 117.92° E), and covers total terrestrial areas of 61 km^2. ACED has been an area dominated by industry for about 25 years, which is mainly divided into Huashan Industrial Zone (HIZ), Hot Springs Resort (HSR), and Integrated Zone (IZ). HIZ is located in the east of the ACED, and contains a lot of enterprises such as foundries, electroplating factories, battery manufacturing plants, and steel cable factories that may discharge heavy metal into the surrounding environment. IZ is situated on the west of ACED, with both enterprises and residential areas, and these enterprises are mostly engaged in metal manufacturing. The northern part of the ACED is HSR, mainly used for agricultural activities and tourism development. In order to determine the characteristics of heavy metal pollution between different regions, Nemerow index was used to evaluate the pollution level of ACED according to the national guide value of soil (GB15618-2018 for Zn and GB 36600-2018 for Cu, Hg, Pb, Ni, Cd, Cr and As). Figure 1 illustrates the fundamental information of ACED.

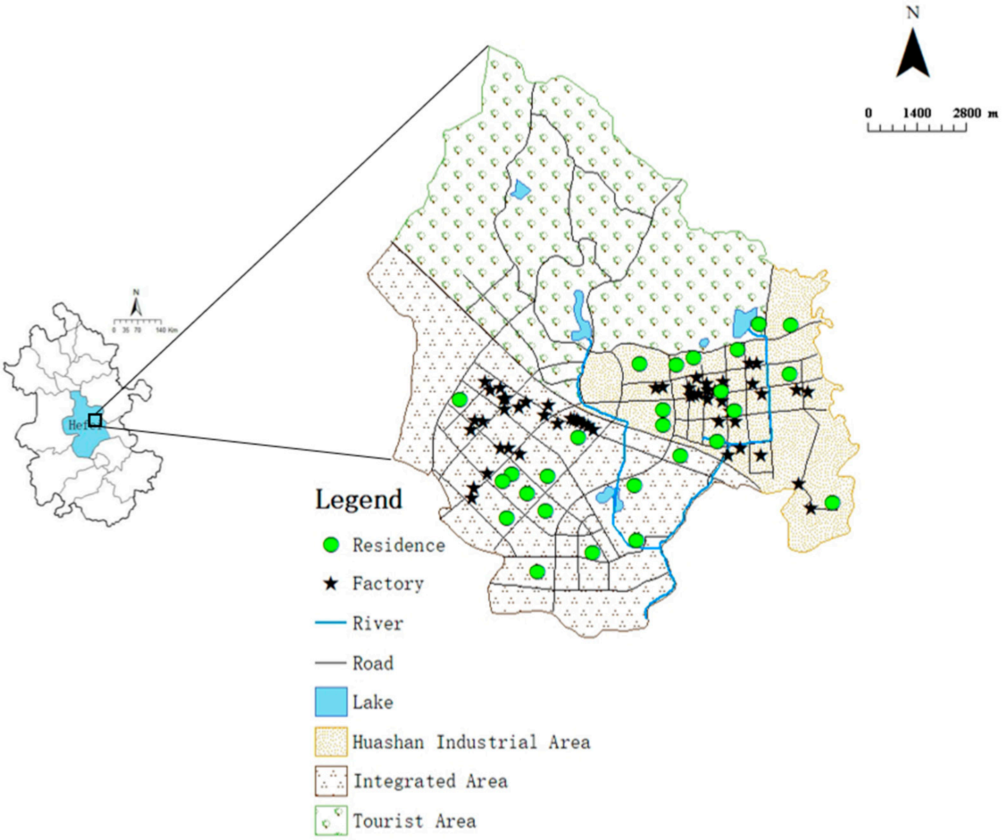

Figure 1. Geographical location and division of major functional areas of Anhui Chaohu economic development Zone.

2.2. Sampling

Soil sampling was carried out in July 2017. The systematic grid sampling method was adopted. A total of 63 samples were selected from ACED (Figure 2). The distance between each sampling point was about 1000 m and adjusted according to the actual terrain. The five-point sampling method was adopted, the distance between each sub-sample was about 1 m, and the sampling depth was 0–20 cm, and then five sub-samples were mixed thoroughly to obtain a sample at the sampling point. All samples were stored in polyester plastic bags and air-dried after removal of stone, sticks, and other debris. After appropriate air-drying, samples were powdered and sieved using a 100-mesh nylon sieve. Determination of Cu, Cr, Cd, Ni, Pb and Zn by using inductively coupled plasma mass spectrometry (ICP-MS), while Hg and As were determined using apply atomic fluorospectro-photometer. The collected soil samples were determined in accordance with the national standard (GB 15618-2018 for Zn and GB 36600-2018 for other heavy metals).

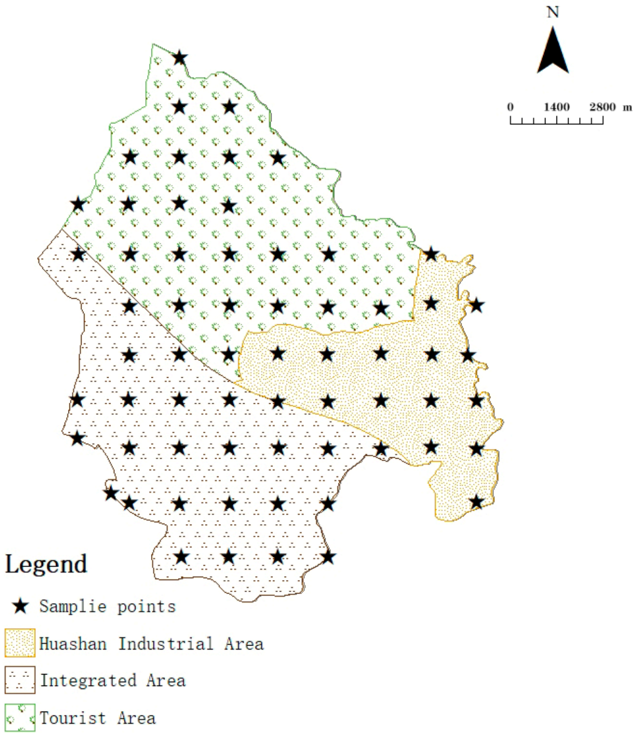

Figure 2. Distribution of sample points in study area.

2.3. Statistical Analysis

Before statistical analysis, the raw data were tested by triplex standard deviation, the test results show that there was no abnormal value. Multivariate statistical analysis including principal component analysis (PCA), cluster analysis (CA), and Pearson correlation analysis was carried out by using SPSS 22 software. ANOVA was used to determine the difference in heavy metal concentration between different regions.

Ordinary Kriging interpolation was performed (using of ArcGIS 10.0) to gain the spatial distribution of heavy metals in ACED topsoil. Before Kriging interpolation, Kolmogrov-Simirnow test (K-S test) was performed to determine whether the raw data have a normal distribution (using of SSPS 22). According to the result of K-S test, Logarithm transformation was performed on the data of Cu, Ni, Pb, As, and square root transformation was performed on the data of Cd and Hg to obtain heavy metal data with normal distribution (the original data of Cr and Zn were in accordance with the normal distribution, no conversion was required). After transformation, Ordinary Kriging interpolation was executed.

2.4. Pollution Assessment

According to the national guide value of soil (GB15618-2018 for Zn and GB 36600-2018 for Cu, Hg, Pb, Ni, Cd, Cr and As), the Nemerow pollution index method was used to assess the degree of soil heavy metal pollution in the study area. The formula is as follows [31]:

$$P_i = \frac{C_i}{S_i} \tag{1}$$

$$\overline{p} = \frac{1}{2}\sum_{i=1}^{n}\frac{C_i}{S_i} \tag{2}$$

$$P_c = \sqrt{\frac{MaxP_i{}^2 + \overline{P}^2}{2}} \quad (3)$$

where P_c is Nemero pollution index, P_i is the over-limit ratio of the heavy metals in surface soil of the study area, C_i is the single heavy metal concentration in surface soil of the study area, and S_i is the guide value of heavy metals in Chinese Environmental Quality Standard for Soils (GB 36600-2018 and GB15618-2018, Table 1). According to the Nemerow index evaluation method, P_c values less than 1 are considered uncontaminated, and P_c values greater than or equal to 1 are considered contaminated. A larger P_c value represents a more serious pollution situation [32].

Table 1. Eight heavy metal concentrations in the study area (mg·kg^{-1}). CV = coefficient of variation. Different lowercase letters on the same line indicate significant differences ($p < 0.05$).

Species	Mean (n = 63)	HSR (n = 22)			IZ (n = 26)			HIZ (n = 15)			Background Value [33]	Guide Value 1	CV (%)
		Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum			
Cu	33.7	33.409 ± 1.75a	21.6	46.3	33.162 ± 1.74a	20.9	49.6	34.9 ± 2.17a	20.5	46.1	24.9	18000	25.036
Zn	166.8	166.545 ± 5.40a	117	207	166.5 ± 6.44a	110	216	167.533 ± 6.88a	120	219	53.2	250	17.087
Cr	62.6	62.195 ± 2.66a	40.8	83.4	65.812 ± 2.91a	40.4	90	57.78 ± 3.04a	40	84.1	69.4	200	21.603
Ni	36.2	40.359 ± 2.77a	15.7	54.6	32.592 ± 2.14b	17.2	50.5	36.5 ± 2.75a	16.2	52.5	25	900	32.952
Cd	0.242	0.247 ± 0.01a	0.163	0.346	0.231 ± 0.01a	0.155	0.337	0.255 ± 0.02a	0.157	0.346	0.104	65	25.44
Pb	34.2	34.682 ± 1.88a	20.3	49.9	33.915 ± 1.72a	20.3	48.6	33.94 ± 2.23a	20	47.7	25.9	800	25.236
Hg	0.268	0.25 ± 0.19a	0.112	0.39	0.27 ± 0.16a	0.114	0.391	0.293 ± 0.22a	0.137	0.399	0.041	38	32.256
As	11.3	11.724 ± 0.98a	5.01	19.3	10.419 ± 0.83a	5.43	19.02	12.203 ± 1.12a	5.28	19.78	9.4	60	38.735

[1] Chinese Environmental Quality Standard for Soils (GB15618-2018 for Zn and GB 36600-2018 for other heavy metals) of 6.5 < pH ≤ 7.5.

3. Results

3.1. Heavy Metal Concentration Characteristics in the Study Area

A descriptive summary of heavy metal measures are presented in Table 1. The maximum concentrations of eight heavy metals in the study area all exceeded their background value and the minimum value of Zn, Hg, and Cr exceeded their background values respectively. The highest average concentrations were observed for Zn, followed by Cr and Ni. The areas with a relatively higher mean value of all heavy metal was mainly observed in HIZ and concentrations of soil heavy metal in HSR and IZ are lower than in HIZ. The concentrations of As in soil varied greatly, ranging from 5.01 to 19.78 mg·kg^{-1}, with the largest coefficient of variation (CV) at 38.735%. The maximum concentration of Hg was approximately ten times as the background value. Although the maximum concentrations of eight heavy metals in the study area exceeded their background values, they did not exceed the guide values. The content of Ni in IZ is significantly lower than that in other regions, and the distribution of heavy metals in other regions has no significant differences between different regions.

3.2. Correlation Analysis of Heavy Metals in the Study Area

Pearson correlation coefficients between eight heavy metals are presented in Table 2. The degree of relationship between two variables can provide information on sources of heavy metal. The results show that the correlation coefficients of As-Zn and As-Cd are 0.259, 0.300 ($p < 0.05$) respectively, which were positively correlated, the correlation coefficients of Ni and Cu are −0.286 ($p < 0.05$) which were negative correlated, and the correlation coefficients of other heavy metals have a smaller correlation coefficient ($p < 0.05$).

Table 2. Pearson correlation coefficients between heavy metals in the study area.

	Cu	**Zn**	**Cr**	**Ni**	**Cd**	**Pb**	**Hg**	**As**
Cu	1							
Zn	0.242	1						
Cr	−0.209	0.06	1					
Ni	−0.286 *	−0.041	−0.128	1				
Cd	−0.074	0.004	−0.197	0.014	1			
Pb	0.097	−0.141	−0.045	−0.073	0.052	1		
Hg	−0.119	−0.149	−0.059	−0.196	−0.059	0.095	1	
As	−0.047	0.259 *	−0.069	0.057	0.300 *	0.081	0.058	1

* Correlation is significant at 0.05 (two-tailed).

3.3. Principal Component Analysis of Heavy Metals in the Study Area

There are four components with eigenvalues greater than unity, so those four components were obtained and listed in Table 3. The principal components 1 (PC1) explains 18.45% of the variance and is composed by Zn, Cd, and As. The PC2 explains 17.5% of the variance and is only composed of Ni. The PC3 explains 16.49% of the variance and is composed by Pb and Hg. The PC4 explains 13.99% of the variance and is composed of Cr, Hg, and As.

Table 3. Principle component analysis for heavy metals in the study area.

Component	PC1	PC2	PC3	PC4
Cu	0.239	−0.547	0.031	−0.315
Zn	0.362	−0.253	−0.375	0.266
Cr	−0.290	−0.072	−0.246	0.591
Ni	0.011	0.481	−0.273	−0.306
Cd	0.406	0.281	0.161	0.022
Pb	0.067	−0.049	0.458	−0.046
Hg	−0.122	0.006	0.493	0.341
As	0.470	0.183	0.052	0.403
% of variance	18.45	17.50	16.49	13.99
% of cumulative	18.45	35.95	52.44	66.43

3.4. Cluster Analysis of Heavy Metals in the Study Area

The results of the cluster analysis show that eight heavy metals were divided into five categories (Figure 3). The first group contains Cd and As. The second group contains Cu and Zn. The third group consists of Pb and Hg. The fourth and the fifth group were Cr and Ni respectively. Among them, the distance between Cd, and As was the smallest, followed by Cu-Zn and Pb-Hg, and the distance between Cr and Ni and other heavy metals was the largest.

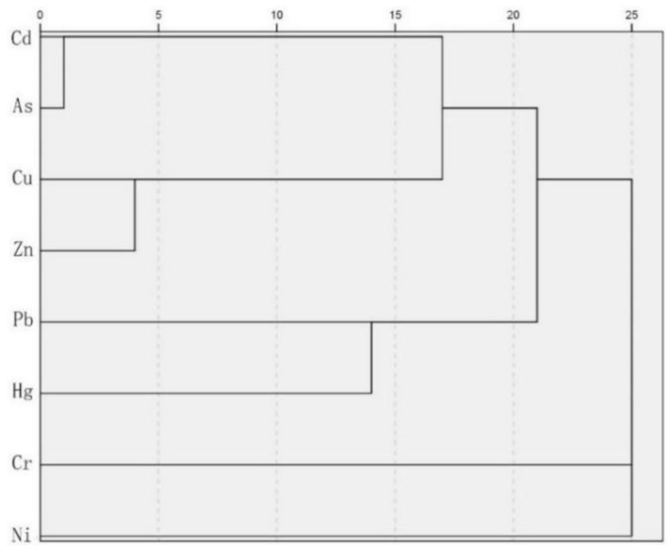

Figure 3. Dendrogram of cluster analysis of eight heavy metals in Anhui Chaohu economic development Zone. The distance between heavy metals indicates the correlation between heavy metals, and the close distance indicates a large correlation.

3.5. Evaluation of Heavy Metal Pollution in the Study Area

Class II guide values of Cu, Pb, As, Cd, Ni, Cr, and Hg in Chinese Environmental Quality Standard for Soils (GB 36600-2018) and Zn in GB15618-2018 was adopted (Table 1), the comprehensive pollution indexes of heavy metals in the study area were calculated. Results of Nemero evaluation show that the heavy metal content of the soil in the study area were within the clean range (Figure 4). Although there was no statistical difference in P_c values between different regions, the P_c values of soil heavy metals were different in different regions, the maximum value of P_c in HSR, IZ, and HIZ was 0.603, 0.616, and 0.632 respectively, and the overall P_c value varied in the order: HIZ > HSR > IZ. Moreover, P_c value changes the most in IZ, while HSR and HIZ have smaller changes.

3.6. Spacial Analysis of Heavy Metals in the Study Area

As shows in Figure 5, the distribution of heavy metals in the study area varies greatly with the different types of heavy metals. The regions with high concentration of As and Cd were HSR, followed by HIZ and IZ. On the contrary, the distribution of Cu and Pb was mainly concentrated in IZ. Interestingly, Ni shows a strong trend of enrichment in HSR, while Hg presents a higher concentration in IZ but rarely in HSR. The distribution of Zn was relatively uniform, and the high concentration areas are mainly allocated in HIZ and HSR. Although Cr was mainly concentrated in HSR and IZ, the distribution of Cr was continuous between different regions, which was quite different from the distribution of other heavy metals.

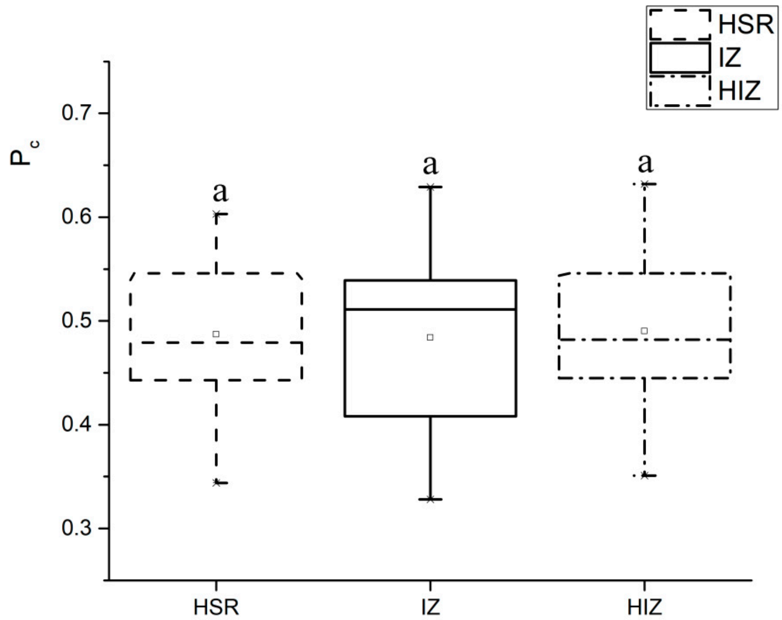

Figure 4. Results of Nemero evaluation of heavy metal content in soils in Anhui Chaohu economic development Zone. HIZ = Huashan Industrial Zone, HSR = Hot Springs Resort, IZ = Integrated Zone, Pc = Nemero pollution index. The lines above and below the box indicate the maximum and minimum values, the upper and lower edges of the box indicate the upper and lower quartiles, and the line inside the box indicates the median the same lowercase letters indicate no significant difference ($p < 0.05$).

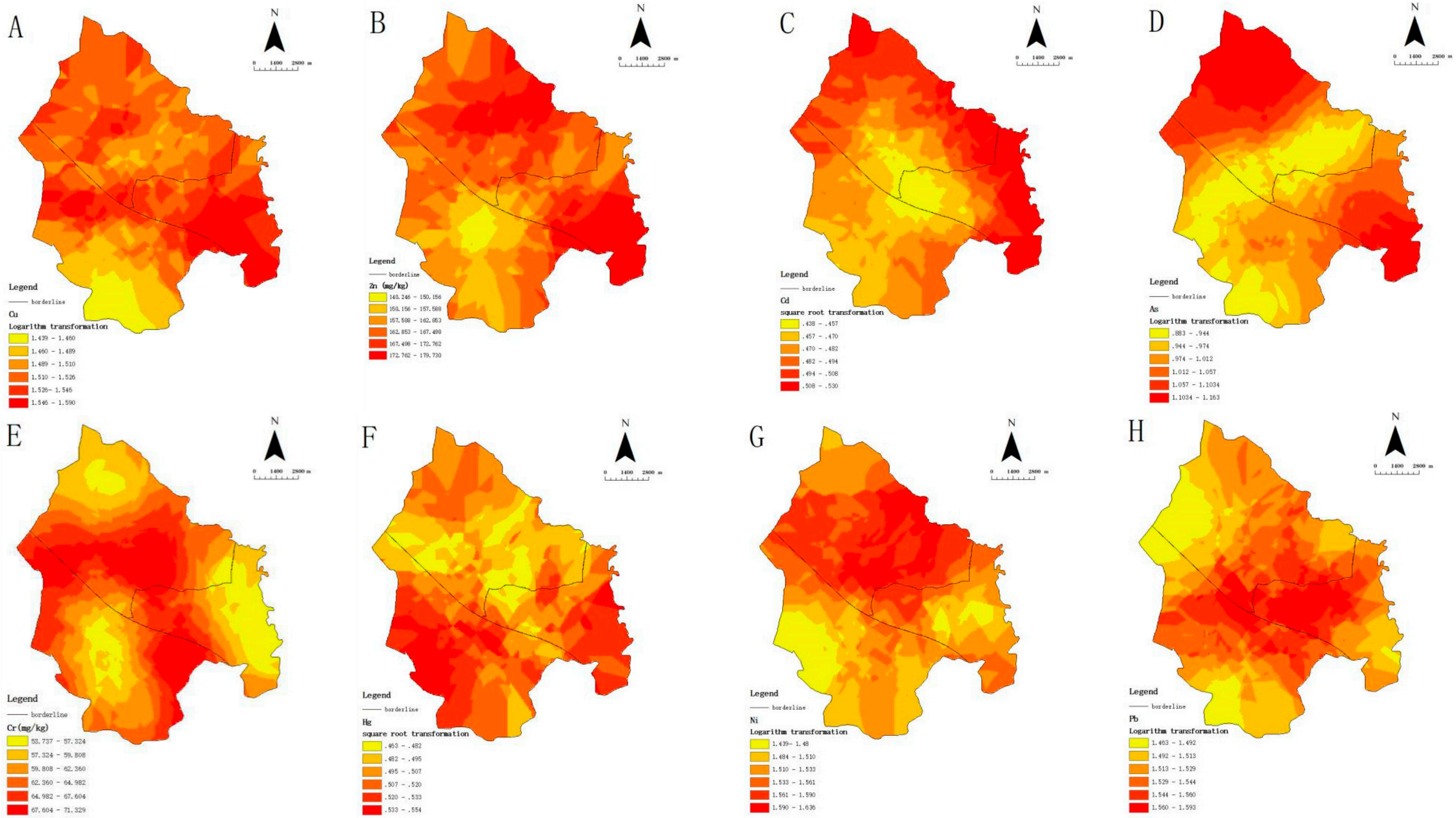

Figure 5. Spatial distribution of heavy metals in Anhui Chaohu economic development Zone. The boundary line refers to the boundary between HSR, IZ and HIZ. The data used for graph drawing of Ni and Zn were original data Cu, Ni, Pb, As were logarithmic conversion, and Cd and Hg were square root conversion. (**A**–**H**) represent Cu, Zn, Cd, As, Cr, Hg, Ni and Pb respectively.

4. Discussion

4.1. The Characteristics of Heavy Metals in HSR Surface Soil

Anthropogenic activities are one of the main factors for the accumulation of heavy metals in the soil. With the development of the economy in china, a large amount of arable land has been used for industrial production or tourism development, which increases the possibility of soil contamination by heavy metals.

HSR has long been used as agricultural land in history. At present, HSR has been developed as a tourist area, with a large number of hot spring hotels, wetlands, and artificial landscapes. Depending on the results of spatial analysis (Figure 5), the areas with higher Ni, As, Cd Zn, and Cr concentration are mainly distributed in HSR. The mean value of Ni, As, Cd Zn, and Cr in HSR were observed higher than other studies on agricultural soils [34,35], but lower than studies on industrial soils [11], indicating that anthropogenic activities may have resulted in the accumulation of heavy metals during historical and current. Although heavy metal in the HSR surface soil did not reach the pollution level (Figure 4), their content increased to varying degrees relative to the background value (Table 1), indicating that there are still external factors affecting the concentration of heavy metal in the HSR surface soil.

Previous surveys expounded that the influence of anthropogenic activities on the soil concentrations of Ni and Cr are low [18,36], and Ni can be transferred into the soil through hot springs [27,37]. In this study, there are many hot springs in HSR. In addition, according to PCA analysis, the PC2 explains 17.5% of the variance and only composed by Ni (Table.3), indicating that the source of Ni in HSR maybe parent materials, reiterated the other researches [27,38]. The concentration of Cr in the study area surface soil with a smaller CV of 21.603%, and low correlation with other elements (Table 2), indicating that Cr was affected by relatively minor anthropogenic activities. Depending on the results of the cluster and spatial analysis (Figures 3 and 5), Cr and Ni were classified into one category, but have the largest distance, indicating that, the main source of Cr in HSR may be the parent materials.

Numerous researchers have suggested that soil contaminated by As and Cd can be attributed to human agriculture activities such as the use of agrochemical, phosphate fertilizers and industrial metallurgy [15,35,39]. In this study, the high correlation between Cd and As was observed (Table 2), and consistent with the results of CA (Figure 3), indicating that Cd and As may originate from the same source. According to the results of the spatial analysis, the areas with a high concentration of Cd and As were mainly distributed in HSR (Figure 5), illustrating that Cd and As in HSR may come from agricultural activities. The areas with a high concentration of Pb Zn were also mainly distributed in HSR (Figure 5), indicating that Zn in the soil of the study area may come from agricultural activities partly, because the use of zinc-containing pesticides may lead to accumulation of Zn in the soil [40], this also explains why As, Cd and Zn composed the PC1 in PCA and the correlation coefficients of As-Zn is a positive correlation (0.259, $p < 0.05$).

Generally, heavy metals in HSR surface soil did not reach the pollution level. However, because the accumulation of heavy metals has been observed, necessary measures must be given to protect the soil in HSR from further heavy metal enrichment.

4.2. The Characteristics of Heavy Metals in HIZ Surface Soil

As the most important economic part of ACED, HIZ is concentrated in many enterprises, including metal processing, metal smelting, and other enterprise types, which may lead to changes in soil heavy metal concentrations. In this study, the concentration of heavy metals in HIZ was generally higher than other industrial land in China [9,11,36], but lower than an industrial zone in Mexico [41] and in India (except for Zn) [12]. Depending on the results of spatial analysis and Nemero evaluation (Figures 4 and 5), although heavy metals in the surface soil of HIZ did not reach pollution levels, the higher heavy metals concentration (except for Ni) in HIZ surface soil were observed, indicating that heavy metals in HIZ surface soil may be affected by relatively intensive anthropogenic activities.

Many researchers have suggested that anthropogenic activities such as improper disposal of electrical conducts and combustion of fossil fuels as well as industrial activities can release Hg into the environment [11,25,27,41]. The concentration of Pb in soil are associated with anthropogenic activities such as the pharmaceutical, battery manufacturing, and waste incineration [11,39], and the traffic is most possibly the major source for the enrichment of Pb in the soils [35].

According to the PCA and CA analysis results, Pb and Hg were classified into one category (Table 3 and Figure 3), indicating that Pb and Hg may originate from the same source. Depending on the results of spatial analysis (Figure 5), the areas with a high concentration of Pb were close to a battery plant and main road, indicating that the concentration of Pb in HIZ was mainly influenced by pollutants released from industrial production and transportation, consistent with previous research [11,35].

Soil contaminated by As and Cd can be attributed to agricultural and industrial activities [33,39]. However, there was almost no agricultural activity in HIZ and the concentration of As in IZ and HIZ were lower than in HSR, indicating that the soil As and Cd in HIZ were mainly influenced by anthropogenic activities such as the foundry's longtime burning of coal [15]. Releases of Cu and Zn from anthropogenic activities is mainly include building materials and metal processing industries [15,18,19,42]. In this study, the regions with a high concentration of Cu and Zn were mainly distributed in HIZ. Therefore, industrial pollutants produced by companies engaged in metal manufacturing in HIZ were likely to be the source of Cu and Zn in HIZ.

Consequently, industrial activities have had a significant impact on soil heavy metals in HIZ, and the trend of heavy metal enrichment was more obvious than in other regions. Therefore, it is necessary to prevent the further accumulation of heavy metals in the soil of HIZ.

4.3. The Characteristics of Heavy Metals in IZ Surface Soil

IZ is mainly composed of residential areas, commercial areas, and some industrial enterprises. Therefore, heavy metals in the surface soil of IZ may be affected by multiple factors and resulting in large differences in soil heavy metal content (Figure 1). This complex land type explains why the Nemero evaluation values has the highest dispersion in IZ soil (Figure 4). Depending on the results of spatial analysis (Figure 5A,F,H), the areas with higher Pb, Hg, and Cu concentration in IZ surface soil were observed, which indicates that the content of Pb, Hg, and Cu in the surface soil of IZ has been affected by external influences. Although the concentrations of eight heavy metals in IZ soil were significantly higher than the background value, they were lower than other studies in urban soils of China [43,44], suggesting a relatively moderate external influence of soil heavy metals when compared to HIZ.

Anthropogenic activities such as improper disposal of electrical conducts and combustion of fossil fuels as well as industrial activities can release Hg into the environment [25,27,41]. The concentration of Pb in the soil are associated with anthropogenic activities such as the pharmaceutical, battery manufacturing, and waste incineration [11,39], and the traffic is most possibly the major source for the enrichment of Pb in the soils [35]. Depending on the results of spatial analysis (Figure 5), different from HIZ, the area with a high concentration of Pb in IZ was close to the main road, indicating that the concentration of Pb in IZ may mainly be influenced by transportation, consistent with previous research results [35]. Hg was mainly distributed in residential areas in IZ (Figure 5F), indicating that the main sources of Hg in IZ may be the vehicle and domestic exhaust [11]. The areas with high Cu concentration in IZ were concentrated near metal processing enterprises. Therefore, similar to HIZ, Cu in IZ surface soil may also originated from industrial activities.

Compared with HIZ and HSR, heavy metals in IZ soil were strongly affected by the diversified land use types and frequent human disturbances. Therefore, in the entire study area, human activities, especially industrial production, were the main factors of soil heavy metal enrichment. Although the concentration of heavy metals in the study area has not exceeded the guide value, effective measures must be taken to prevent further heavy metal enrichment.

5. Conclusions

In this study, the concentrations, spatial distribution and sources of Cu, As, Cr, Ni, Cd, Zn, Hg and Pb in Anhui Chaohu Economic Development Zone (ACED), surface soil were determined respectively. The preliminary result shows that the maximum concentrations of eight heavy metals in the study area all exceeded their background value but did not exceed the guide values. The results of Nemelo evaluation show that heavy metals in ACED surface soil are at the clean level. The highest average concentrations were observed for Zn, followed by Cr and Ni. The concentrations of As in soils ranging from 5.01 to 19.78 mg/kg, with the largest coefficient of variation (CV) at 38%.

Distributions of heavy metals in different functional areas were varied, the areas with higher As, Cd and Ni concentrations were mainly distributed in HSR, while the relatively higher concentrations of Cr and Zn were mainly distributed in HIZ and HSR. The concentration of Cu and Pb in different regions was HSR > IZ > HIZ. In addition, IZ soil has the highest Hg content. Moreover, all heavy metals (except for Ni) have higher content in the surface soil of HIZ. The distribution of heavy metal sources location was uneven and mainly distributed in HIZ and IZ. Further analysis showed that soil Cd, Hg, Pb, and Cu were predominantly influenced by industrial activities, As were predominantly originated from agricultural activities Cr and Ni were mainly controlled by parent material. Consequently, the concentration of Cd, Hg, Pb and Cu of soil in the study area was significantly affected by anthropogenic activities, especially in HIZ, and the necessary attention of soil heavy metal needs to be given.

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