applied sciences

MDPI

Article

Characteristics, Sources and Health Risk of Heavy Metals in Road Dust in the Typical County Town, Central China

Wenmin Chen [1,2], Xihao Zhang [1,2], Jiaquan Zhang [2,*], Ning Duan [1], Xiangyi Gong [1], Shan Liu [2], Changlin Zhan [2], Wei Chen [3] and Xinli Xing [3]

1 School of Resources and Environmental Engineering, Wuhan University of Science and Technology, Wuhan 430081, China
2 Hubei Key Laboratory of Mine Environmental Pollution Control and Remediation, School of Environmental Science and Engineering, Hubei Polytechnic University, Huangshi 435003, China
3 School of Environmental Studies, China University of Geosciences, Wuhan 430074, China
* Correspondence: zhangjiaquan@hbpu.edu.cn

Abstract: In this study, to investigate the contamination characteristics and potential health implications of heavy metals in road dust of the typical county in central China, heavy metals (Cd, Co, Cr, Cu, Mn, Ni, V, Pb, Zn) in typical road dust with large traffic flow, in different functional areas of Yangxin County, were determined. The results of the geo-accumulation index (I_{geo}) showed that Co, Mn, Ni, and V were not polluted, while other heavy metals caused different degrees of pollution. According to principal component analysis (PCA), there were three main sources of heavy metals. The result of statistical analysis showed that heavy metal pollution in road dust mainly comes from traffic activities, industrial production activities, building pollution, and the natural environment. The carcinogenic and non-carcinogenic risks of children and adults were within the safe range, and hand–oral contact was the main exposure route of non-carcinogenic risks. The non-carcinogenic risk and carcinogenic effects of heavy metals in urban road dust were acceptable to children and adults. However, we should still pay attention to the impact of heavy metals on the ecological environment and human health.

Keywords: road dust; toxic elements; pollution; health risk

Citation: Chen, W.; Zhang, X.; Zhang, J.; Duan, N.; Gong, X.; Liu, S.; Zhan, C.; Chen, W.; Xing, X. Characteristics, Sources and Health Risk of Heavy Metals in Road Dust in the Typical County Town, Central China. *Appl. Sci.* **2022**, *12*, 12958. https://doi.org/10.3390/app122412958

Academic Editor: Zhujian Huang

Received: 15 August 2022
Accepted: 14 December 2022
Published: 16 December 2022

1. Introduction

In China, due to dust particles, the rapid growth in urbanization and industrialization has increased the risk of pollution in road areas. The fine particles can be suspended into the atmosphere again through the action of wind, pedestrians, and traffic [1,2]. Most of the pollutants are persistent in road dust, and road dust resuspension is a source of air pollution [3,4]. Several studies mentioned that road dust particle suspension has a significant impact on human health in Kuwait [5], India [6], and Korea [7]. Road dust may cause direct and indirect adverse effects on fauna, flora, and human health on the regional scale [8]. Road dust also has a socioeconomic impact on health [9], the oil sector [10], and photovoltaic energy efficiency [11]. Studies have shown that road fine dust particles (<63 µm radius diameter dust particles) can not only be suspended into the atmosphere but also be exposed more easily to humans [12]. Due to the diverse components and complex sources of urban road dust, it carries a large number of heavy metal elements and has also become the main research object of heavy metal pollution in the urban environment [13], and the content of heavy metals enriched in urban road dust is significantly higher in comparison to that in urban surface soil [14]. Besides, urban road dust has various components and complex sources. It contains many toxic, universal, and persistent heavy metal elements. Heavy metals are absorbed by the human body and will continue to bioaccumulate in key organs (such as the brain, liver and kidney) for a long time, which will have adverse effects on health [15–18]. Therefore, it is necessary to estimate the harm of heavy metal pollutants caused by urban dust to human health through different exposure pathways. Since the 1970s, research on urban dust pollution has been carried out on a global scale, focusing on the characteristics, sources, and health risks of heavy metals in the dust on urban roads [19–24].

The current research concentrates on the distribution characteristics, source identification, accumulation rules, potential risks to human health, and environmental effects of heavy metals in road dust, and it usually focuses on large cities with dense populations, developed economies and industries, and high urbanization. At present, the most concerning heavy metal elements are Cd, Cu, Cr, Ni, Pb, and Zn, among which Cu, Pb, and Zn are also called "urban elements" [25–27]. Inevitably, a large volume of wastewater containing Cr, Cd, Cu, Ni, Pb, and other metal elements is discharged by the electroplating industry [28]. Cu may cause serious damages or necrotizing changes to the liver, kidney, and central nervous system [29]. Cr, Cd, Ni, and Pb can induce cancer to a certain extent [30].

Since the implementation of China's rural revitalization strategy, the economy has achieved great development [31]. For example, Yangxin County, Hubei Province, combined with its advantageous industries, actively docked industrial patents in developed regions and made full use of the national major regional strategy to the county. In addition, it has a leading role in strengthening investment promotion, and thus, the economy of Yangxin County has achieved dramatic development. Yangxin County has a population more than one million. However, with the rapid development of the economy and urbanization, the contradiction between economic development and environmental pollution has become increasingly obvious. Yangxin County is a typical copper-rich and zinc-rich mineral area with frequent smelting activities, which emit significant dust and slag rich in toxic heavy metals into the surrounding environment.

This study took Yangxin County as the object and selected different types of roads in the old town (OT), the Economic Development Zone (EDZ), and the Chengdong New District (CND). It collected dust samples and tested the content of heavy metals (Cd, Co, Cr, Cu, Mn, Ni, V, Pb, and Zn) in road dust. The date can be used to support theoretical guidance and the decision-making basis for improving regional environmental quality. The main objectives are: (1) to study the distribution of heavy metals in different functional areas; (2) to evaluate heavy metals pollution by the geo-accumulation index (I_{geo}); (3) to determine the possible sources of heavy metals by multivariate statistical analysis; (4) to evaluate the impact of heavy metal pollution in dust on human health.

2. Materials and Methods

2.1. Study Area

Yangxin County is located on the south bank of the middle reaches of the Yangtze River, which is at the northern foot of the Mufu Mountain Range and in the southeastern part of Hubei Province. With an average annual temperature of 16.8 °C and an average annual rainfall of 1389.6 mm, it is a northern subtropical climate zone. There are a lot of types of mineral deposits and large reserves. Yangxin is famous for its minerals in China, containing over 40 kinds of proven mineral deposits, China's eight major copper production bases, as well as being one of the hundred key coal mining counties. The main industries include light industry, auto parts, machinery, electronics, logistics, chemical industry, and metallurgy. Additionally, it is an important logistics and commercial distribution center in the adjacent areas of the three provinces (Hunan, Hubei, and Jiangxi Province).

On 15 October 2019, 48 total samples were collected on different types of roads collected in three areas in Yangxin County (Figure 1). There were about 150,000 people in the 10 square kilometers of OT and about 200,000 people in the 12 square kilometers of CND. Population density of the study area was between 15,000 and 16,667 persons/km^2. Firstly, clean plastic dustpans and brushes were used to collect dust and transfer the collected road dust to polyethylene sealed bags (the five dust samples were mixed into one sample, which was evenly arranged in range of 10 m × 10 m), and the samples were numbered. Secondly, environment and weather information was recorded (temperature, wind speed, humidity, and pressure). Then, the samples were taken to the laboratory. The samples were dried naturally at room temperature, screened through a 200-mesh (75 μm) standard sieve, and dust samples under the sieve were collected for testing.

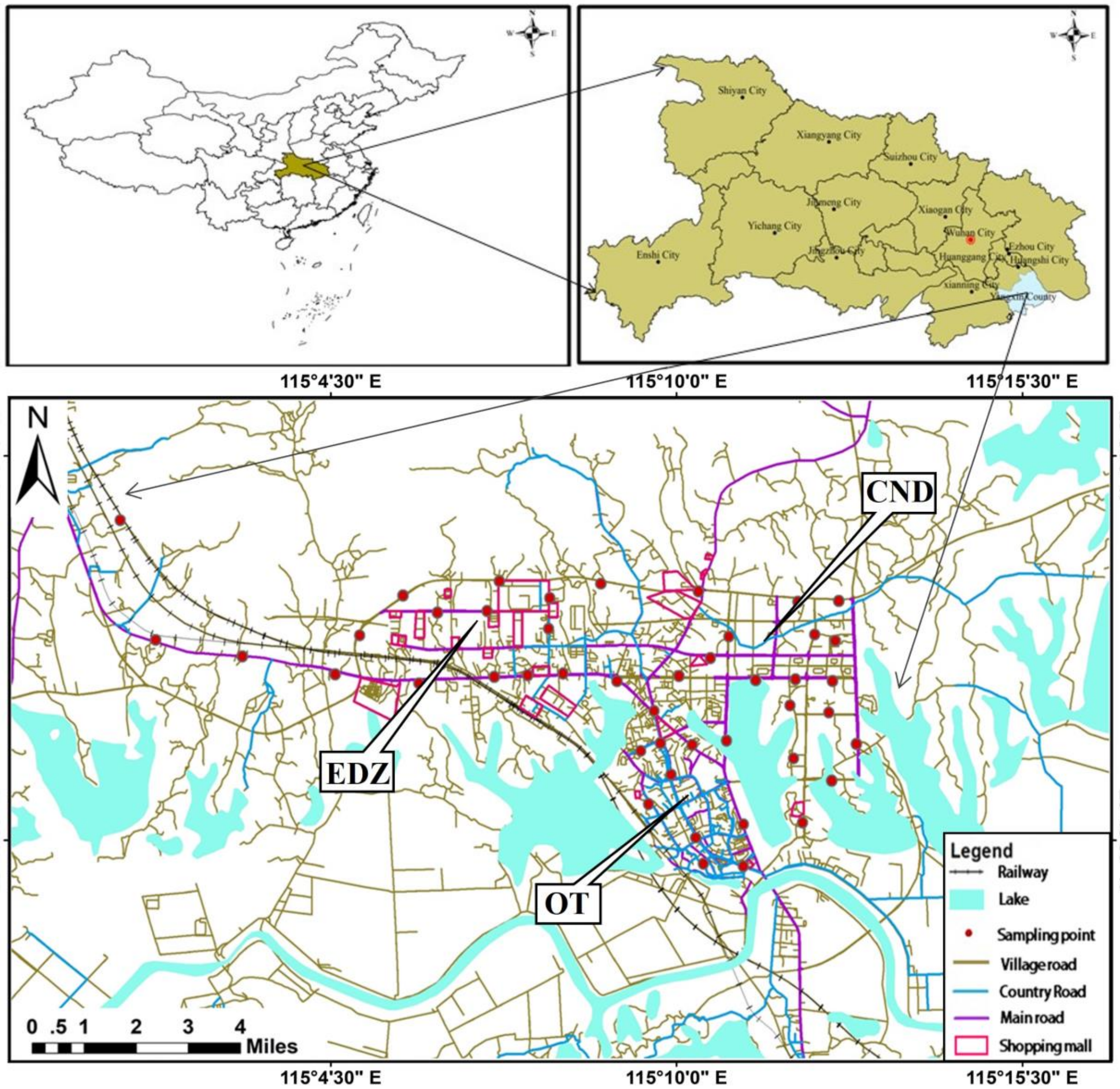

Figure 1. Distribution of sampling points of road dust.

2.2. Sample Analysis

After natural air drying, 0.2000 g dust samples of the sieve were placed into the 50 mL crucible, and three replicates of dust samples (n = 3) were obtained at every five sampling sites. The HCl–HNO_3–HF–$HClO_4$ wet digestion method was used to analyze the samples for pretreatment, inductively coupled plasma optical emission spectrometry (ICP-OEC, ICAP7200 Radial, Thermo Fisher, Waltham, MA, USA) was used to determine Co, Cr, Cu, Mn, Ni, V, Pb, Zn in dust samples, and inductively coupled plasma source mass spectrometry (ICP-MS, NexION1000, Perkin-Elmer) was used to determine Cd. In the experiment, various chemical reagents all had high-grade purity. All the utensils were soaked in aqua regia for more than 24 h, and the relative standard deviation (RSD) of the sample analysis was less than 10%. At the same time, the recovery rate of the analysis process was controlled with the national standard soil sample (GSS-3), and the recovery rate of the measured elements was greater than 90%.

2.3. Geo-Accumulation Index

The geo-accumulation index (I_{geo}) was proposed to evaluate the heavy metal pollution in sediments by Muller [32], and it was also used to identify heavy metal pollution in road dust [33,34]. The function is as shown in Equation (1):

$$I_{geo} = \log_2 \frac{C_n}{k \times B_n} \tag{1}$$

where C_n is the measured concentration of the nth heavy metal in the road dust, mg/kg; k is the correction coefficient used to consider the changes in the environmental background value that may be caused by diagenesis (usually 1.5); B_n is the metal geochemical background value, mg/kg. This study took the soil environmental background value of Hubei Province [35] as the surface dust background value. The pollution status was classified into seven grades based on I_{geo} [36].

2.4. Health Risk Assessment

In this study, the health risk assessment model issued by the United States Environmental Protection Agency (USEPA) [37,38] was employed to evaluate the health risks caused by dust exposure to urban residents in Yangxin County. The calculation model formulas of the pollutant exposures ADD_{ing}, ADD_{inh}, and ADD_{derm}, through the hand–oral contact intake, respiratory inhalation, and skin contact, are shown as Equations (2)–(4). The calculation model of the lifelong average exposure dose of carcinogenic heavy metal inhalation is shown as Equation (5).

$$ADD_{ing} = C \times \frac{EF \times ED \times R_{ing}}{AT \times BW} \times 10^{-6} \tag{2}$$

$$ADD_{inh} = C \times \frac{EF \times ED \times R_{inh}}{AT \times BW \times PEF} \tag{3}$$

$$ADD_{derm} = C \times \frac{EF \times ED \times AF \times SA \times ABS}{AT \times BW} \times 10^{-6} \tag{4}$$

$$LADD_{inh} = \frac{C \times EF}{PEF \times AT} \times \left(\frac{R_{inh}^{child} \times ED_{child}}{BW_{child}} + \frac{R_{inh}^{adult} \times ED_{adult}}{BW_{adult}}\right) \tag{5}$$

where ADD_{ing}, ADD_{inh}, and ADD_{derm} are the non-carcinogenic exposures of pollutants in the three routes of hand–oral contact, inhalation, and skin contact, mg/(kg·d); $LADD_{inh}$ is the average daily exposure amount of carcinogenic heavy metals inhalation, mg/(kg·d); C is the heavy metal content of road dust, mg/kg. The meanings and sources of other parameters were shown in literature [36].

The total non-carcinogenic and carcinogenic risks of various types of heavy metal pollution in dust to the human body can be calculated by Equations (6) and (7).

$$HI = \sum HQ_i = \sum \frac{ADD_{ij}}{RfD_{ij}} \tag{6}$$

$$R_T = \sum R_i = \sum LADD_{ij} \times SF_{ij} \tag{7}$$

where HI is the total non-carcinogenic risk; RfD is the reference dose; R_T is the total carcinogenic risk; SF is the carcinogenic slope factor, standing for the probability of human exposure to a certain pollutant causing cancer. When HI < 1, the risk is small or negligible. When HI > 1, it indicates that there is a non-carcinogenic health risk. According to the USEPA standard, $R_i < 10^{-6}$ is considered to have no carcinogenic risk, and $R_i > 10^{-4}$ is considered to have a significant carcinogenic risk [39]. Table 1 showed the reference doses and carcinogenic slopes of various heavy metals in different exposure routes.

Table 1. Reference doses and slope factors for different exposure routes of heavy metals.

Project	Cd	Co	Cr	Cu	Mn	Ni	V	Pb	Zn
RfD_{ing}	1.00×10^{-3}	3.00×10^{-4}	3.00×10^{-3}	4.00×10^{-2}	4.60×10^{-2}	2.00×10^{-2}	7.00×10^{-3}	3.50×10^{-3}	3.00×10^{-1}
RfD_{inh}	1.00×10^{-3}	5.71×10^{-6}	2.86×10^{-5}	4.02×10^{-2}	5.00×10^{-5}	2.06×10^{-2}	7.00×10^{-3}	3.52×10^{-3}	3.00×10^{-1}
RfD_{derm}	1.00×10^{-5}	1.60×10^{-2}	6.00×10^{-5}	1.20×10^{-2}	1.84×10^{-3}	5.40×10^{-3}	7.00×10^{-5}	5.25×10^{-4}	6.00×10^{-2}
SF	6.3	9.8	42	-	-	0.84	-	-	-

2.5. Statistical Analyses

Descriptive statistics (maximum, minimum, mean, standard deviation, coefficient of variation, Pearson's correlation analysis (P'CA), principal component analysis (PCA), and Cluster analysis) of the research data used SPSS26 (IBM SPSS). KMO (Kaiser–Meyer–Olkin) test and Bartlett sphericity test were used to test the applicability of the original PCA data set. ArcGIS 10.5 (ESRI, Redlands, CA, USA) was applied to mapping, and ordinary Kriging was adopted for interpolating the concentrations of all metals.

3. Results and Discussion

3.1. Distribution Characteristics of Heavy Metals

The contents of heavy metals in road dust in Yangxin County were shown in Table 2. The average contents of Cd, Co, Cr, Cu, Mn, Ni, V, Pb, and Zn were 1.48, 12.75, 185.89, 123.11, 587.78, 34.75, 87.80, 48.30, and 205.23 mg/kg, respectively, which were 8.63, 0.83, 2.16, 4.01, 0.83, 0.93, 0.80, 1.81, and 2.45 times the soil background value of Hubei Province.

Table 2. Heavy metals contents in road dust in Yangxin County, mg·kg^{-1}.

Sampling Area		Cd	Co	Cr	Cu	Mn	Ni	V	Pb	Zn
EDZ	Mean	1.91	12.09	195.47	122.39	595.53	27.54	85.41	49.04	182.01
	Max	11.11	15.63	462.23	478.51	879.44	55.51	126.83	77.69	308.77
	Min	0.05	8.97	53.59	32.09	350.42	13.82	42.56	13.72	66.87
	SD	2.59	1.93	116.18	140.64	138.46	10.74	20.57	19.84	80.68
	CV	136	16	59	115	23	39	24	40	44
OT	Mean	1.30	11.88	161.36	122.13	549.70	34.51	85.29	57.17	230.71
	Max	8.71	28.69	262.27	381.47	1214.71	75.92	124.29	204.11	429.98
	Min	0.01	8.24	63.85	53.10	354.93	18.60	66.14	17.09	92.20
	SD	2.00	4.80	58.54	97.04	186.99	14.66	14.76	40.28	80.23
	CV	154	40	36	79	34	42	17	70	35
CND	Mean	1.24	14.27	200.85	124.83	618.09	42.22	92.71	38.69	202.98
	Max	11.25	46.06	559.05	832.94	966.42	222.54	142.11	169.96	511.56
	Min	0.06	8.32	71.42	18.99	419.12	13.08	71.10	11.94	55.26
	SD	2.61	8.54	126.90	188.61	133.39	50.19	15.08	34.98	101.19
	CV	209	60	63	151	22	119	16	90	50
SUN	Mean	1.48	12.75	185.89	123.11	587.78	34.75	87.80	48.30	205.23
	Max	11.25	46.06	559.05	832.94	1214.71	222.54	142.11	204.11	511.56
	Min	0.01	8.24	53.59	18.99	350.42	13.08	42.56	11.94	55.26
	SD	2.44	5.87	106.37	146.94	157.43	31.40	17.36	33.72	90.15
	CV	164	46	57	119	27	90	20	70	44
Background value of soil		0.17	15.40	86.00	30.70	712.00	37.30	110.20	26.70	83.60

Obviously, these nine heavy metals were enriched in road dust to varying degrees. These results showed that there was heavy metal pollution in road dust in Yangxin County. The coefficient of variation (CV) can reflect the influence of human activities on the content of heavy metals to some extent. The larger the CV, the greater the change of heavy metal content in the spatial scale and the impact of human interference. If the CV was greater than 50%, it was considered that the spatial distribution of heavy metals was heterogeneous, and the existence of local point pollution sources should be considered [40]. The order of

CV was Cd (164%) > Cu (119%) > Ni (90%) > Pb (70%) > Cr (57%) > Co (46%) > Zn (44%) > Mn (27%) > V (20%). The CV of Cd, Cr, Cu, Ni, and Pb exceeded 50%, indicating that these elements were unevenly distributed in different pavement areas of Yangxin County, and they were considered as local pollution sources or artificial non-point pollution sources. The CV of Mn and V were 27% and 20%, and it was considered that the two metals were homogeneously distributed.

The statistical analysis of heavy metal content in road dust samples in Yangxin County was carried out, and the analysis results were shown in Figure 2. Research showed that the sources of heavy metals in road dust were affected by human factors [27,41]. The spatial distribution patterns were obviously different in the study area. Generally, the high contents of Pb, Zn, and Ni coincided with metal smelting, auto parts, machinery manufacturing, and other leading industries [42]. The relatively high Cu content may be related to the development of the modern logistics industry in the region because the wear of automobile brake pads will lead to the input of copper in dust [43,44]. The copper mine in Yangxin County accounted for 25.23% of the identified reserves in Hubei Province. Therefore, the influence of natural factors, such as wind, was also one of the reasons for the enrichment of copper [45]. The high content of Cd and Cr in OT was mainly due to the impact of traffic activities. The OT was the main living area of residents [46,47]. There were many public places, such as shops, schools, and hospitals, as well as crowded people and high traffic flow, so car braking frequency was high, and car brakes, brake pads, tire wear, and other human activities will cause Cd, Cr, and Cu to fall on the ground [48,49]. There was no significant difference in the content of V in the three different functional areas, which may be related to the dense greening on both sides of the road and more soil particles in the road dust. At the same time, as a major mining County, Yangxin County had high Zn and Cr contents and large reserves of common and associated minerals. Therefore, mining and other activities were also the reasons for the high content of Zn and Cr in road dust [50,51].

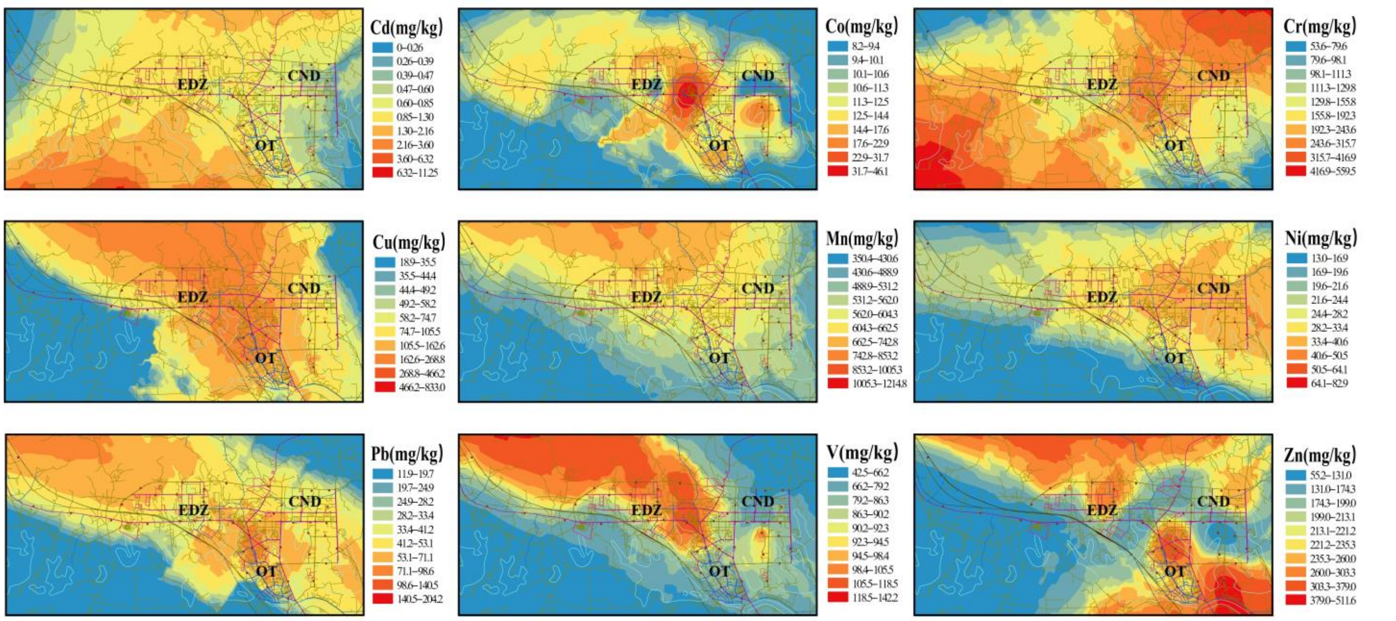

Figure 2. Distribution characteristics of heavy metal content in road dust in Yangxin County.

From the perspective of different road types in the three regions, the content of Cr, Cu, and Zn in the main roads of OT and EDZ was higher than that of CND. This may be related to the industry, modern logistics, smelting, parts manufacturing, etc. in the special economic zone. The high content of Cr, Cu, and Zn in the trunk roads of OT is associated with the large traffic flow, the large number of people, and intersections with traffic lights.

Cu, Zn, and other elements entered the road environment due to the frequent start and stop times of the vehicle and the frequent use of brakes. The highest content of Cd and Ni were in the branch road of OT, while Cd and Ni were related to people's daily travel and coal combustion. At present, OT is the main living area of residents in Yangxin County. Dense population, daily travel, heating, and other activities will lead to high contents of Cd and Ni on the branch. The content of each element in the three types of roads in CND was high, which was mainly because CND was in the stage of infrastructure construction, with relatively high passenger and vehicle flows and frequent construction activities.

3.2. Evaluation of the I_{geo}

It can be seen from Figure 3 that the order of the average I_{geo} of heavy metals in road dust in Yangxin County was Cd (2.52) > Cu (1.42) > Zn (0.71) > Cr (0.53) > Pb (0.27) > Ni (−0.69) > Mn (−0.86) > Co (−0.86) > V (−0.91). According to I_{geo} classification, Cd presented moderately to heavily contaminated, Cu presented moderately, Cr, Pb, and Zn presented uncontaminated to moderately contaminated, and Co, Mn, Ni, and V presented not polluted. The average I_{geo} of nine types of heavy metals in the EDZ, OT, and CND areas were 1.11, 1.05, and 0.79 respectively, indicating that the heavy metal pollution in high-density human activity areas was significantly higher than that in low-density human activity areas. In addition, heavy metal pollution of road dust was related to human production and life [52–54]. The average I_{geo} of the heavy metals in the whole area was 0.98, and the overall pollution level was slightly polluted, indicating the low pollution level of road dust in the urban area of Yangxin County. However, there were also some pollution phenomena that need to be paid attention. Combined with the distribution characteristics of road dust emission, the distribution characteristics of heavy metal content in road dust, and the evaluation of heavy metal pollution degree, it can be concluded that most heavy metal elements showed obvious differences in high and low concentrations. In addition, this difference was consistent with the high-density and low-density ranges of human activity areas.

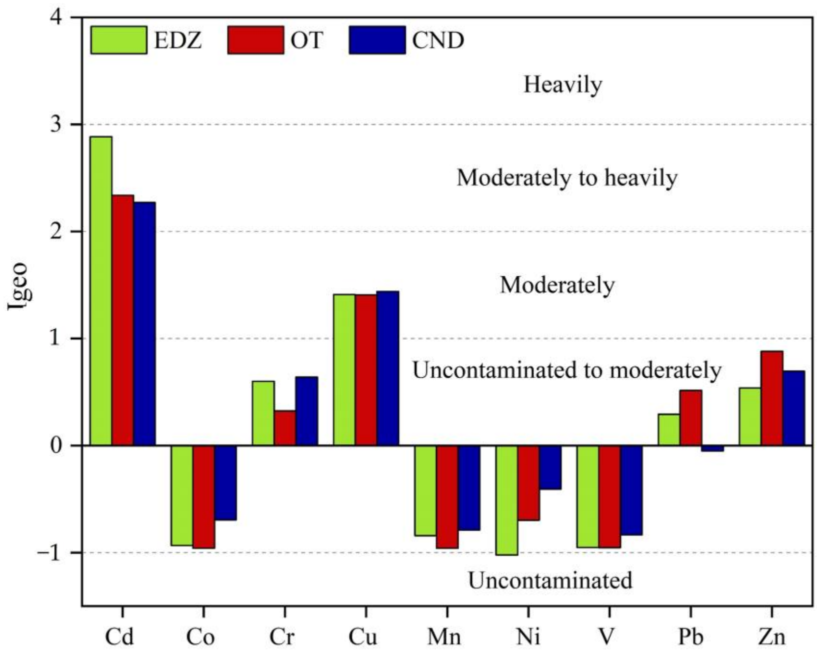

Figure 3. I_{geo} distribution map of road dust and heavy metals in different areas of Yangxin County.

3.3. Source Identification of Heavy Metals

3.3.1. Pearson's Correlation Analysis

The Pearson's correlation analysis results of road dust in Yangxin County were shown in Table 3. Positive correlations existed between the heavy metals. Cd, Cu, Ni, Pb, and

Zn showed significant positive correlation at $p < 0.01$. Except Cr-V (r = 0.126), Co, Cr, Mn, and V showed significant positive correlation at $p < 0.01$. There were positive correlations, suggesting an analogous origin of these elements. In the road dust samples with heavy traffic, the contents of Cd, Cu, Ni, Pb, and Zn were high, and their sources may be related to the exhaust emissions, tire wear, and the wear and corrosion of alloys [55].

Table 3. Correlation coefficients for heavy metals in road dust in Yangxin County.

Elements	Correlation Coefficient								
	Cd	**Co**	**Cr**	**Cu**	**Mn**	**Ni**	**V**	**Pb**	**Zn**
Cd	1								
Co	0.059	1							
Cr	0.245	0.53 **	1						
Cu	0.558 **	0.177	0.312 **	1					
Mn	0.019	0.576 **	0.431 **	0.265	1				
Ni	0.534 **	0.303 *	0.535 **	0.65 **	0.236	1			
V	−0.014	0.623 **	0.126	0.349 *	0.617 **	0.08	1		
Pb	0.619 **	0.008	0.159	0.728 **	0.019	0.477 **	0.122	1	
Zn	0.379 **	0.003	0.225	0.639 **	0	0.472 **	0.051	0.662 **	1

** Reflects a significance level of 0.01. * Significance level of 0.05.

3.3.2. Principal Component Analysis

In order to explore the relationship between the contents of heavy metals in road dust and the sources of pollutants in Yangxin County, principal component analysis (PCA) was carried out by SPSS. KMO (Kaiser–Meyer–Olkin) test and Bartlett sphericity test were used to test the heavy metal content (KMO = 0.708, Bartlett = 0.000). After rotating by the Kaiser normalization maximum variance method, three principal components with eigenvalues greater than 1 were extracted, and they accounted for 77.478% of the total variance (Table 4), which can better represent the information contained in the data. Cd (0.707), Cu (0.866), Pb (0.909), and Zn (0.802) were strong positive loadings in the PC1, and the variance contribution rate was 34.658% (Table 5). Cd and Cu were the most commonly used materials in cables and electrical and electronic components, which can be used to form many kinds of alloys and coatings [56,57]. Pb and Zn were mainly affected by traffic activities. Tire wear and corrosion may cause substances containing Pb or Zn to accumulate in road dust [58,59]. Co (0.747), Mn (0.803), and V (0.937) were higher in the PC2, and the variance contribution rate was 24.843%. Co, Mn, and V had low mean contents and were close to their background values. They were less affected by human activities. It was inferred that these elements were from the natural environment. Therefore, PC2 might be the natural source. Cr (0.883) and Ni (0.635) were higher in the PC3, and the variance contribution rate was 17.977%. Cr and Ni were the main elements added to stainless steel [60,61]. They were also used in electroplating, metallurgy, and other industrial activities. Therefore, PC3 might be the industrial source.

3.3.3. Cluster Analysis

Z-score was used to standardize the heavy metal content data, and Ward's clustering algorithm was used to cluster analysis the nine kinds of heavy metals (Figure 4). The nine heavy metals were divided into three clusters: cluster 1 was Cd-Cu-Pb-Zn, cluster 2 was Cr-Ni, and cluster 3 was Co-V-Mn. However, there was still a moderate correlation between the clusters. Cd-Cu-Pb-Zn cluster and Cr-Ni cluster were connected, indicating that their sources may be the same. The maximum content of Cd-Cu-Zn and Cr-Ni appeared in CND, while CND was in the stage of infrastructure construction with higher traffic flow, construction, and demolition activities [62–64].

Table 4. Eigenvalues and cumulative contribution rates obtained from a heavy metal factor analysis of road dust in Yangxin County.

Factor	Initial Eigenvalues			Before Rotation			After Rotation		
	Eigenvalues	Variance Percentage (%)	Accumulative Contribution Rate (%)	Eigenvalues	Variance Percentage (%)	Accumulative Contribution Rate (%)	Eigenvalues	Variance Percentage (%)	Accumulative Contribution Rate (%)
1	3.733	41.479	41.479	3.733	41.479	41.479	3.119	34.658	34.658
2	2.222	24.690	66.169	2.222	24.690	66.169	2.236	24.843	59.502
3	1.018	11.309	77.478	1.018	11.309	77.478	1.618	17.977	77.478
4	0.618	6.866	84.344						
5	0.435	4.836	89.180						
6	0.373	4.141	93.321						
7	0.257	2.851	96.171						
8	0.216	2.401	98.572						
9	0.128	1.428	100.000						

Extraction method: principal component analysis; rotation method: maximum variance rotation.

Table 5. Factor loads associated with heavy metals in surface dust in Yangxin County.

Elements	After Rotation		
	PC1	PC2	PC3
Cd	0.707	−0.111	0.292
Co	−0.046	0.747	0.468
Cr	0.133	0.236	0.883
Cu	0.866	0.283	0.133
Mn	0.000	0.803	0.295
Ni	0.602	0.074	0.635
V	0.133	0.937	−0.148
Pb	0.909	0.027	−0.014
Zn	0.802	−0.018	0.060

Extraction method: principal component analysis; rotation method: maximum variance rotation.

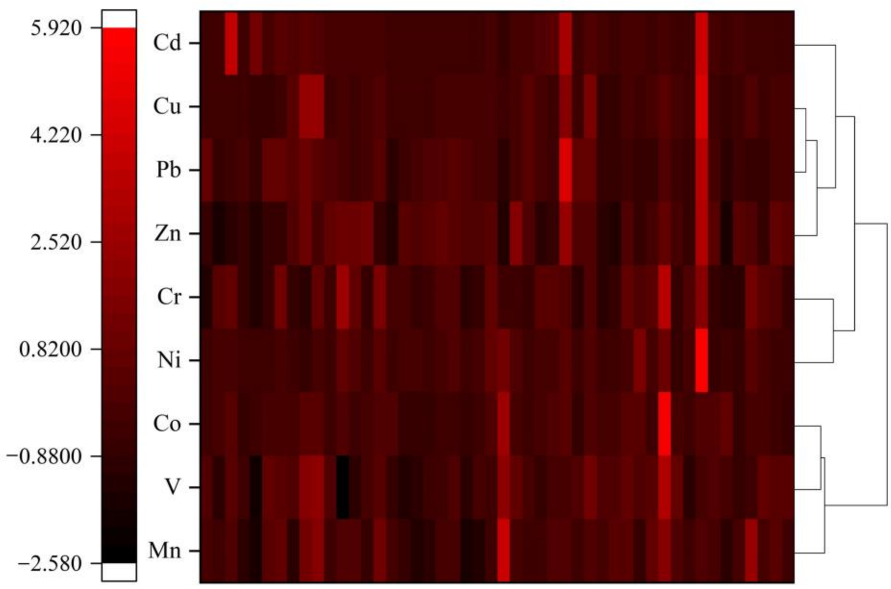

Figure 4. Cluster analysis of heavy metals in the dust.

3.4. Health Risk Assessment

It can be seen from Table 6 that the order of daily average exposure doses of nine kinds of heavy metals, for children and adults, was Mn > Zn > Cu > V > Pb > Cr > Ni > Co > Cd. The order of non-carcinogenic exposure doses of children and adults was ADD_{ing} > ADD_{derm} > ADD_{inh}. The exposure doses of the hand–oral intake route accounted for a relatively high proportion of the total exposure dose, reaching 99.05%

and 98.67%. Obviously, the hand–oral intake route was the most important route of road dust exposure [65–67]. The exposure dose of children to road dust was higher than that of adults, indicating that children were more threatened by road dust [68–70]. The results were consistent with those reported in other studies [71,72].

Table 6. Health risks of heavy metals in road dust in Yangxin County.

Population	Risk	Cd	Co	Cr	Cu	Mn	Ni	V	Pb	Zn
Child	ADD_{ing}	4.88×10^{-7}	4.19×10^{-6}	6.11×10^{-5}	4.72×10^{-4}	2.25×10^{-3}	1.14×10^{-5}	3.37×10^{-4}	1.85×10^{-4}	7.87×10^{-4}
	ADD_{inh}	1.20×10^{-10}	1.03×10^{-9}	1.50×10^{-8}	1.16×10^{-7}	5.53×10^{-7}	2.80×10^{-9}	8.25×10^{-8}	4.54×10^{-8}	1.93×10^{-7}
	ADD_{derm}	4.56×10^{-9}	3.91×10^{-8}	5.70×10^{-7}	4.41×10^{-6}	2.10×10^{-5}	1.07×10^{-7}	3.14×10^{-6}	1.73×10^{-6}	7.35×10^{-6}
	HQ_{ing}	4.88×10^{-4}	1.40×10^{-2}	2.04×10^{-2}	1.18×10^{-2}	4.90×10^{-2}	5.71×10^{-4}	4.81×10^{-2}	5.29×10^{-2}	2.62×10^{-3}
	HQ_{inh}	1.20×10^{-7}	1.80×10^{-4}	5.24×10^{-4}	2.88×10^{-6}	1.11×10^{-2}	1.36×10^{-7}	1.18×10^{-5}	1.29×10^{-5}	6.43×10^{-7}
	HQ_{derm}	4.56×10^{-4}	2.44×10^{-6}	9.51×10^{-3}	3.67×10^{-4}	1.14×10^{-2}	1.97×10^{-5}	4.49×10^{-2}	3.29×10^{-3}	1.22×10^{-4}
	HI	9.44×10^{-4}	1.42×10^{-2}	3.04×10^{-2}	1.22×10^{-2}	7.15×10^{-2}	5.91×10^{-4}	9.30×10^{-2}	5.62×10^{-2}	2.75×10^{-3}
Adult	ADD_{ing}	2.96×10^{-7}	2.54×10^{-6}	3.70×10^{-5}	2.86×10^{-4}	1.37×10^{-3}	6.92×10^{-6}	2.04×10^{-4}	1.12×10^{-4}	4.77×10^{-4}
	ADD_{inh}	5.51×10^{-11}	4.73×10^{-10}	6.90×10^{-9}	5.33×10^{-8}	2.54×10^{-7}	1.29×10^{-9}	3.80×10^{-8}	2.09×10^{-8}	8.88×10^{-8}
	ADD_{derm}	3.93×10^{-9}	3.38×10^{-8}	4.92×10^{-7}	3.80×10^{-6}	1.82×10^{-5}	9.21×10^{-8}	2.71×10^{-6}	1.49×10^{-6}	6.34×10^{-6}
	HQ_{ing}	2.96×10^{-4}	8.46×10^{-3}	1.23×10^{-2}	7.15×10^{-3}	2.97×10^{-2}	3.46×10^{-4}	2.91×10^{-2}	3.21×10^{-2}	1.59×10^{-3}
	HQ_{inh}	5.51×10^{-8}	8.28×10^{-5}	2.41×10^{-4}	1.33×10^{-6}	5.09×10^{-3}	6.26×10^{-8}	5.43×10^{-6}	5.94×10^{-6}	2.96×10^{-7}
	HQ_{derm}	3.93×10^{-4}	2.11×10^{-6}	8.21×10^{-3}	3.17×10^{-4}	9.87×10^{-3}	1.70×10^{-5}	3.88×10^{-2}	2.84×10^{-3}	1.06×10^{-4}
	HI	6.89×10^{-4}	8.55×10^{-3}	2.08×10^{-2}	7.47×10^{-3}	4.47×10^{-2}	3.63×10^{-4}	6.79×10^{-2}	3.49×10^{-2}	1.70×10^{-3}
R		1.10×10^{-9}	1.47×10^{-8}	9.19×10^{-7}			3.44×10^{-9}			

The non-carcinogenic risks of heavy metals in road dust, through three exposure routes, was V > Mn > Pb > Cr > Co > Cu > Zn > Cd > Ni. The order of non-carcinogenic risk was $HQ_{ing} > HQ_{derm} > HQ_{inh}$. The results showed that no significant non-carcinogenic risk was found for all measured heavy metals in the study areas since the HQi and HI values were <1 [36,73]. The non-carcinogenic risk of children was higher than that of adults but lower than the allowable limit. Adults' health risks were relatively low [74–76]. The maximum single non-carcinogenic risk of the three exposure routes was 0.068, indicating that road dust did not pose a non-carcinogenic risk to adults. However, the possibility that these metals may cause serious health effects through their accumulation in body tissues still exists.

In terms of carcinogenic risk, the order of carcinogenic risk of the four carcinogenic elements was Cr > Co > Ni > Cd. The range of carcinogenic risk in the study area was 1.1×10^{-9}–9.19×10^{-7}, while lower than 1×10^{-6} was the accepted. However, there were still some deficiencies in the current risk assessment research. For example, the soil background value was used to replace the lack of surface dust background value; there were other potentially toxic metals (e.g., Sb, Fe, As, etc.) and organic pollutants (e.g., polycyclic aromatic hydrocarbons, microplastics, etc.) in the dust, which have not been evaluated [77,78]. Therefore, more research on other pollutants is needed in the future.

4. Conclusions

The average concentrations of Cd, Cr, Cu, Pb, and Zn in the road dust in Yangxin County were higher than the soil environmental background values in Hubei Province and were obviously enriched. Cd pollution in dust was the most serious, showing moderate to severe pollution, Cu was moderate pollution, Cr, Pb, and Zn were not polluted to moderate pollution, and Co, Mn, Ni, and V were not polluted. The heavy metal pollution levels were consistent in EDZ, OT, and CND (except Pb). Traffic activities, industrial production activities, building pollution, and the natural environment were the main sources of heavy metals in urban road dust. Hand–oral ingestion was the main exposure route of non-carcinogenic risk. The non-carcinogenic risks and carcinogenic effects of heavy metals in urban road dust were acceptable to children and adults. Therefore, we should pay attention to the impact of heavy metals on the ecological environment and human health. Plantation, using native plants and green belts, has contributed to the reduction in the annual rates of mobile sand and dust [79,80]. The use of native cultivation was efficient in controlling pollution [81–84]; therefore, dense cultivations with native vegetation should take place to reduce the pressure on the ecological environment.

Author Contributions: The study was designed and supervised by J.Z.; statistical analysis and manuscript writing, W.C. (Wenmin Chen); Writing—original draft preparation, X.Z.; language editing N.D. and X.G.; field and laboratory work, S.L. and C.Z.; project administration W.C. (Wei Chen) and X.X. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the financial support of the National Key R&D Program of China, grant number 2017YFC0212602; the Hubei Universities of Outstanding Young Scientific and Technological Innovation Team Plans, grant number T201729.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All the data analyzed/generated are included and available in the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Zheng, N.; Hou, S.N.; Wang, S.J.; Sun, S.Y.; An, Q.R.; Li, P.Y.; Li, X.Q. Health risk assessment of heavy metals in street dust around a zinc smelting plant in China based on bioavailability and bioaccessibility. *Ecotoxicol. Environ. Saf.* **2020**, *197*, 110617. [CrossRef] [PubMed]
2. Zhao, N.; Lu, X.W.; Chao, S.G.; Xu, X. Multivariate statistical analysis of heavy metals in less than 100 μm particles of street dust from Xining, China. *Environ. Earth Sci.* **2015**, *73*, 2319–2327. [CrossRef]
3. Roy, S.; Gupta, S.K.; Prakash, J.; Habib, G.; Kumar, P. A global perspective of the current state of heavy metal contamination in road dust. *Environ. Sci. Pollut. Res.* **2022**, *29*, 33230–33251. [CrossRef] [PubMed]
4. Rienda, I.C.; Alves, C.A. Road dust resuspension: A review. *Atmos. Res.* **2021**, *261*, 105740. [CrossRef]
5. Al-Dousari, A.; Ramadan, A.; Al-Qattan, A.; Al-Ateeqi, S.; Dashti, H.; Ahmed, M.; Al-Dousari, N.; Al-Hashash, N.; Othman, A. Cost and effect of native vegetation change on aeolian sand, dust, microclimate and sustainable energy in Kuwait. *J. Taibah Univ. Sci.* **2020**, *14*, 628–639. [CrossRef]
6. Mahato, M.K.; Singh, A.K.; Giri, S. Assessment of metal pollution and human health risks in road dust from mineral rich zone of East Singhbhum, India. *Environ. Geochem. Health* **2022**. [CrossRef] [PubMed]
7. Jeong, H.; Ra, K. Source apportionment and health risk assessment for potentially toxic elements in size-fractionated road dust in Busan Metropolitan City, Korea. *Environ. Monit. Assess.* **2022**, *194*, 350. [CrossRef]
8. Alshemmari, H.; Al-Dousari, A.M.; Talebi, L.; Al-Ghadban, A.N. Mineralogical Characteristics of Surface Sediments along Sulaibikhat Bay, Kuwait. *Kuwait J. Sci. Eng.* **2013**, *40*, 159–176.
9. Doronzo, D.M.; Al-Dousari, A. Preface to Dust Events in the Environment. *Sustainability* **2019**, *11*, 628. [CrossRef]
10. Subramaniam, N.; Al-Sudairawi, M.; Al-Dousari, A.; Al-Dousari, N. Probability distribution and extreme value analysis of total suspended particulate matter in Kuwait. *Arab. J. Geosci.* **2015**, *8*, 11329–11344. [CrossRef]
11. Ahmed, M.M.; Al-Dousari, A.M.; Baby, S. Chemical and morphological characteristics of phytogenic mounds (nabkhas) in Kuwait. *Arab. Gulf J. Sci. Res.* **2009**, *27*, 114–123.
12. Zhang, J.; Wu, L.; Zhang, Y.J.; Li, F.H.; Fang, X.Z.; Mao, H.J. Elemental composition and risk assessment of heavy metals in the PM10 fractions of road dust and roadside soil. *Particuology* **2019**, *44*, 146–152. [CrossRef]
13. Shabanda, I.S.; Koki, I.B.; Low, K.H.; Zain, S.M.; Khor, S.M.; Abu-Bakar, N.K. Daily exposure to toxic metals through urban road dust from industrial, commercial, heavy traffic, and residential areas in Petaling Jaya, Malaysia: A health risk assessment. *Environ. Sci. Pollut. Res.* **2020**, *26*, 37193–37211. [CrossRef]
14. Zhang, L.Y.; Guo, S.H.; Wu, B. The Source, Spatial Distribution and Risk Assessment of Heavy Metals in Soil from the Pearl River Delta Based on the National Multi-Purpose Regional Geochemical Survey. *PLoS ONE* **2015**, *10*, e0132040. [CrossRef]
15. Khan, M.N.; Sarwar, A. Chemical composition of wet precipitation of air pollutants: A case study in Karachi, Pakistan. *Atmosfera* **2014**, *27*, 35–46. [CrossRef]
16. Abdullah, M.; Fasola, M.; Muhammad, A.; Malik, S.A.; Bostan, N.; Bokhari, H.; Kamran, M.A.; Shafqat, M.N.; Alamdar, A.; Khan, M. Avian feathers as a non-destructive bio-monitoring tool of trace metals signatures: A case study from severely contaminated areas. *Chemosphere* **2015**, *119*, 553–561. [CrossRef]
17. Melik, K. Assessment of sources and pollution state of trace and toxic elements in street dust in a metropolitan city. *Environ. Geochem. Health* **2020**, *42*, 3213–3229. [CrossRef]
18. Wahab, M.I.A.; Razak, W.M.A.A. Assessment of trace elements concentration in road dust around the city of Kuala Lumpur. *IOP Conf. Ser. Mater. Sci. Eng.* **2019**, *572*, 012116. [CrossRef]

19. Idris, A.M.; Alqahtani, F.M.S.; Said, T.O.; Fawy, K.F. Contamination level and risk assessment of heavy metal deposited in street dusts in Khamees-Mushait city, Saudi Arabia. *Hum. Ecol. Risk Assess.* **2018**, *26*, 495–511. [CrossRef]
20. Ball, J.E.; Jenks, R.; Aubourg, D. An assessment of the availability of pollutant constituents on road surfaces. *Sci. Total Environ.* **1998**, *209*, 243–254. [CrossRef]
21. Zgłobicki, W.; Telecka, M. Heavy Metals in Urban Street Dust: Health Risk Assessment (Lublin City, E Poland). *Appl. Sci.* **2021**, *11*, 4092. [CrossRef]
22. Hussain, K.; Rahman, M.; Prakash, A.; Hoque, R.R. Street dust bound PAHs, carbon and heavy metals in Guwahati city-Seasonality, toxicity and sources. *Sustain. Cities Soc.* **2015**, *19*, 17–25. [CrossRef]
23. Živančev, J.R.; Ji, Y.; Škrbić, B.D.; Buljovčić, M.B. Occurrence of heavy elements in street dust from sub/urban zone of Tianjin: Pollution characteristics and health risk assessment. *J. Environ. Sci. Health Part A Toxic/Hazard. Subst. Environ. Eng.* **2019**, *54*, 999–1010. [CrossRef] [PubMed]
24. Trojanowska, M.; Świetlik, R. Investigations of the chemical distribution of heavy metals in street dust and its impact on risk assessment for human health, case study of Radom (Poland). *Hum. Ecol. Risk Assess.* **2020**, *26*, 1907–1926. [CrossRef]
25. Charlesworth, S.; Everett, M.; McCarthy, R.; Ordóñez, A.; de-Miguel, E. A comparative study of heavy metal concentration and distribution in deposited street dusts in a large and a small urban area: Birmingham and Coventry, West Midlands, UK. *Environ. Int.* **2003**, *29*, 563–573. [CrossRef]
26. Ahmad, H.R.; Mehmood, K.; Sardar, M.F.; Maqsood, M.A.; Rehman, M.Z.U.; Zhu, C.X.; Li, H.N. Integrated risk assessment of potentially toxic elements and particle pollution in urban road dust of megacity of Pakistan. *Hum. Ecol. Risk Assess.* **2020**, *26*, 1810–1831. [CrossRef]
27. Wahab, M.I.A.; Abd-Razak, W.M.A.; Sahani, M. Characteristics and health effect of heavy metals on non-exhaust road dusts in Kuala Lumpur. *Sci. Total Environ.* **2020**, *703*, 135535. [CrossRef]
28. Ilyas, N.; Ilyas, S.; Rahman, S.; Yousaf, S.; Zia, A.; Sidra, S. Removal of copper from an electroplating industrial effluent using the native and modified spirogyra. *Water Sci. Technol.* **2018**, *78*, 147–155. [CrossRef]
29. Jun, M.; Srivastava, R.R.; Jeong, J.; Lee, J.-C.; Kim, M.-S. Simple recycling of copper by the synergistic exploitation of industrial wastes: A step towards sustainability. *Green Chem.* **2016**, *18*, 3823–3834. [CrossRef]
30. Wu, G.F.; Wang, L.L.; Yang, R.; Hou, W.X.; Zhang, S.W.; Guo, X.Y.; Zhao, W.J. Pollution characteristics and risk assessment of heavy metals in the soil of a construction waste landfill site. *Ecol. Inform.* **2022**, *70*, 101700. [CrossRef]
31. Zhou, Y.; Li, Y.M.; Xu, C.C. Land consolidation and rural revitalization in China: Mechanisms and paths. *Land Use Policy* **2020**, *91*, 104379. [CrossRef]
32. Muller, G. Index of geoaccumulation in sediments of the Rhine River. *Geojournal* **1969**, *2*, 108–118.
33. Almeida, T.S.; Santana, M.O.; Cruz, J.M.; Tormen, L.; Bascunan, V.L.A.F.; Azevedo, P.A.; Garcia, C.A.B.; Alves, J.D.H.; Araujo, R.G.O. Characterisation and source identification of the total airborne particulate matter collected in an urban area of Aracaju, North-east, Brazil. *Environ. Pollut.* **2017**, *226*, 444–451. [CrossRef]
34. Aguilera, A.; Bautista, F.; Gutiérrez-Ruiz, M.; Ceniceros-Gomez, A.E.; Cejudo, R.; Goguitchaichvili, A. Heavy metal pollution of street dust in the largest city of Mexico, sources and health risk assessment. *Environ. Monit. Assess.* **2021**, *193*, 193. [CrossRef]
35. China Environmental Monitoring Center. *Background Values of Soil Elements in China*; China Environmental Science Press: Beijing, China, 1990.
36. Shabbaj, I.I.; Alghamdi, M.A.; Shamy, M.; Hassan, S.K.; Alsharif, M.M.; Khoder, M.I.; Ibrahim, I.S. Risk Assessment and Implication of Human Exposure to Road Dust Heavy Metals in Jeddah, Saudi Arabia. *Int. J. Environ. Res. Public Health* **2018**, *15*, 36. [CrossRef]
37. US EPA. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*; United States Environmental Protection Agency: Washington, DC, USA, 2002.
38. US EPA. Risk Assessment Guidance for Superfund. In *Volume I Human Health Evaluation Manual (Part A)*; United States Environmental Protection Agency: Washington, DC, USA, 1989.
39. Roy, S.; Gupta, S.K.; Prakash, J.; Habib, G.; Baudh, K.; Nasr, M. Ecological and human health risk assessment of heavy metal contamination in road dust in the National Capital Territory (NCT) of Delhi, India. *Environ. Sci. Pollut. Res.* **2019**, *26*, 30413–30425. [CrossRef]
40. Han, Q.; Wang, M.S.; Cao, J.L.; Gui, C.L.; Liu, Y.P.; He, X.D.; He, Y.C.; Liu, Y. Health risk assessment and bioaccessibilities of heavy metals for children in soil and dust from urban parks and schools of Jiaozuo, China. *Ecotoxicol. Environ. Saf.* **2020**, *191*, 110157. [CrossRef]
41. Men, C.; Liu, R.M.; Wang, Q.R.; Guo, L.J.; Shen, Z.Y. The impact of seasonal varied human activity on characteristics and sources of heavy metals in metropolitan road dusts. *Sci. Total Environ.* **2018**, *637*, 844–854. [CrossRef]
42. Jayarathne, A.; Egodawatta, P.; Ayoko, G.A.; Goonetilleke, A. Role of residence time on the transformation of Zn, Cu, Pb and Cd attached to road dust in different land uses. *Ecotoxicol. Environ. Saf.* **2018**, *153*, 195–203. [CrossRef]
43. Hjortenkrans, D.; Bergbäck, B.; Häggerud, A. New metal emission patterns in road traffic environments. *Environ. Monit. Assess.* **2006**, *117*, 85–98. [CrossRef]
44. Huang, S.; Taddei, P.; Lawrence, J.; Martins, M.A.G.; Li, J.; Koutrakis, P. Trace element mass fractions in road dust as a function of distance from road. *J. Air Waste Manage. Assoc.* **2021**, *71*, 137–146. [CrossRef] [PubMed]

45. Gulia, S.; Goyal, P.; Goyal, S.K.; Kumar, R. Re-suspension of road dust: Contribution, assessment and control through dust suppressantsa review. *Int. J. Environ. Sci. Technol.* **2019**, *16*, 1717–1728. [CrossRef]
46. Krupnova, T.G.; Rakova, O.V.; Gavrilkina, S.V.; Antoshkina, E.G.; Baranov, E.O.; Yakimova, O.N. Road dust trace elements contamination, sources, dispersed composition, and human health risk in Chelyabinsk, Russia. *Chemosphere* **2020**, *261*, 127799. [CrossRef] [PubMed]
47. Maeaba, W.; Prasad, S.; Chandra, S. First Assessment of Metals Contamination in Road Dust and Roadside Soil of Suva City, Fiji. *Arch. Environ. Contam. Toxicol.* **2019**, *77*, 249–262. [CrossRef] [PubMed]
48. Laribi, A.; Shand, C.; Wendler, R.; Mouhouche, B.; Colinet, G. Concentrations and sources of Cd, Cr, Cu, Fe, Ni, Pb and Zn in soil of the Mitidja plain, Algeria. *Toxicol. Environ. Chem.* **2019**, *101*, 59–74. [CrossRef]
49. Esposito, F.; Memoli, V.; Di-Natale, G.; Trifuoggi, M.; Maisto, G. Quercus ilex L. leaves as filters of air Cd, Cr, Cu, Ni and Pb. *Chemosphere* **2019**, *218*, 340–346. [CrossRef]
50. Song, B.; Guo, G.H.; Lei, M.; Wang, Y.W. Assessments of contamination and human health risks of heavy metals in the road dust from a mining county in Guangxi, China. *Hum. Ecol. Risk Assess.* **2018**, *24*, 1606–1622. [CrossRef]
51. Yang, J.; Teng, Y.G.; Song, L.T.; Zuo, R. Tracing Sources and Contamination Assessments of Heavy Metals in Road and Foliar Dusts in a Typical Mining City, China. *PLoS ONE* **2016**, *11*, e0168528. [CrossRef]
52. Ochiagha, K.E.; Okoye, P.A.C.; Eboagu, N.C. The Geo-accumulation Index of Some Heavy Metals in the Roadsides Soils of Onitsha South Local Government Area Anambra State, Nigeria. *Sci. J. Chem.* **2020**, *8*, 42–47. [CrossRef]
53. Palanivel, T.M.; Victor, R. Contamination assessment of heavy metals in the soils of an abandoned copper mine in Lasail, Northern Oman. *Int. J. Environ. Stud.* **2020**, *77*, 432–446. [CrossRef]
54. Liu, M.; Xu, Y.X.; Nawab, J.; Rahman, Z.; Khan, S.; Idress, M.; Ud, Z.D.; Ali, A.; Ahmad, R.; Khan, S.A. Contamination features, geo-accumulation, enrichments and human health risks of toxic heavy metal(loids) from fish consumption collected along Swat river, Pakistan. *Environ. Technol. Innov.* **2020**, *17*, 100554. [CrossRef]
55. Pan, H.Y.; Lu, X.W.; Lei, K. A comprehensive analysis of heavy metals in urban road dust of Xi'an, China: Contamination, source apportionment and spatial distribution. *Sci. Total Environ.* **2018**, *609*, 1361–1369. [CrossRef]
56. Yeung, Z.L.L.; Kwok, R.C.W.; Yu, K.N. Determination of multi-element profiles of street dust using energy dispersive X-ray fluorescence (EDXRF). *Appl. Radiat. Isot.* **2003**, *58*, 339–346. [CrossRef]
57. Zhang, G.X.; Shao, L.Z.; Li, F.L.; Yang, F.; Wang, J.M.; Jin, Z.F. Bioaccessibility and health risk assessment of Pb and Cd in urban dust in Hangzhou, China. *Environ. Sci. Pollut. Res.* **2020**, *27*, 11760–11771. [CrossRef]
58. Adaniec, E.; Jarosz-Krzeminska, E. Human Health Risk Assessment associated with contaminants in the finest fraction of sidewalk dust collected in proximity to trafficked roads. *Sci. Rep.* **2019**, *9*, 16364. [CrossRef]
59. Al-Shidi, H.K.; Sulaiman, H.; Al-Reasi, H.A.; Jamil, F.; Aslam, M. Human and ecological risk assessment of heavy metals in different particle sizes of road dust in Muscat, Oman. *Environ. Sci. Pollut. Res.* **2020**, *28*, 33980–33993. [CrossRef]
60. Dhal, B.; Thatoi, H.N.; Das, N.N.; Pandey, B.D. Chemical and microbial remediation of hexavalent chromium from contaminated soil and mining/ metallurgical solid waste: A review. *J. Hazard. Mater.* **2013**, *250*, 272–291. [CrossRef]
61. Su, X.M.; Ling, H.; Wu, D.; Xue, Q.J.; Xie, L.Q. Spatial-Temporal Variations, Ecological Risk Assessment, and Source Identification of Heavy Metals in the Sediments of a Shallow Eutrophic Lake, China. *Toxics* **2022**, *10*, 16. [CrossRef]
62. Saeedi, M.; Li, L.Y.; Salmanzadeh, M. Heavy metals and polycyclic aromatic hydrocarbons: Pollution and ecological risk assessment in street dust of Tehran. *J. Hazard. Mater.* **2012**, *227*, 9–17. [CrossRef]
63. Cai, A.Z.; Zhang, H.X.; Wang, L.T.; Wang, Q.; Wu, X.Q. Source Apportionment and Health Risk Assessment of Heavy Metals in PM2.5 in Handan: A Typical Heavily Polluted City in North China. *Atmosphere* **2021**, *12*, 1232. [CrossRef]
64. Kaonga, C.C.; Kosamu, I.B.M.; Utembe, W.R. A Review of Metal Levels in Urban Dust, Their Methods of Determination, and Risk Assessment. *Atmosphere* **2021**, *12*, 891. [CrossRef]
65. Hu, B.B.; Liu, B.Q.; Zhou, J.; Guo, J.T.; Sun, Z.B.; Meng, W.Q.; Guo, X.; Duan, J.H. Health risk assessment on heavy metals in urban street dust of Tianjin based on trapezoidal fuzzy numbers. *Hum. Ecol. Risk Assess.* **2016**, *22*, 678–692. [CrossRef]
66. Al-Shidi, H.K.; Al-Reasi, H.A.; Sulaiman, H. Heavy metals levels in road dust from Muscat, Oman: Relationship with traffic volumes, and ecological and health risk assessments. *Int. J. Environ. Health Res.* **2020**, *32*, 264–276. [CrossRef] [PubMed]
67. Zhang, X.; Zhang, K.; Lv, W.L.; Liu, B.; Aikawa, M.; Wang, J.H. Characteristics and risk assessments of heavy metals in fine and coarse particles in an industrial area of central China. *Ecotoxicol. Environ. Saf.* **2019**, *179*, 1–8. [CrossRef] [PubMed]
68. Pragg, C.; Mohammed, F.K. Distribution and health risk assessment of heavy metals in road dust from an industrial estate in Trinidad, West Indies. *Int. J. Environ. Health Res.* **2020**, *30*, 336–343. [CrossRef]
69. Rahman, M.S.; Khan, M.D.H.; Jolly, Y.N.; Kabir, J.; Akter, S.; Salam, A. Assessing risk to human health for heavy metal contamination through street dust in the Southeast Asian Megacity: Dhaka, Bangladesh. *Sci. Total Environ.* **2019**, *660*, 1610–1622. [CrossRef]
70. Li, Z.Y.; Liang, T.; Li, K.X.; Wang, P. Exposure of children to light rare earth elements through ingestion of various size fractions of road dust in REEs mining areas. *Sci. Total Environ.* **2020**, *743*, 140432. [CrossRef]
71. Li, H.H.; Chen, L.J.; Yu, L.; Guo, Z.B.; Shan, C.Q.; Lin, J.Q.; Gu, Y.G.; Yang, Z.B.; Yang, Y.X.; Shao, J.R.; et al. Pollution characteristics and risk assessment of human exposure to oral bioaccessibility of heavy metals via urban street dusts from different functional areas in Chengdu, China. *Sci. Total Environ.* **2017**, *586*, 1076–1084. [CrossRef]

72. Wang, J.H.; Li, S.W.; Cui, X.Y.; Li, H.M.; Qian, X.; Wang, C.; Sun, Y.X. Bioaccessibility, sources and health risk assessment of trace metals in urban park dust in Nanjing, Southeast China. *Ecotoxicol. Environ. Saf.* **2016**, *128*, 161–170. [CrossRef]
73. Lu, A.X.; Li, B.R.; Li, J.; Chen, W.; Xu, L. Heavy metals in paddy soil-rice systems of industrial and township areas from subtropical China: Levels, transfer and health risks. *J. Geochem. Explor.* **2018**, *194*, 210–217. [CrossRef]
74. Moryani, H.T.; Kong, S.Q.; Du, J.K.; Bao, J.G. Health Risk Assessment of Heavy Metals Accumulated on PM2.5 Fractioned Road Dust from Two Cities of Pakistan. *Int. J. Environ. Res. Public Health* **2020**, *17*, 7124. [CrossRef]
75. Al-osman, M.; Yang, F.; Massey, I.Y. Exposure routes and health effects of heavy metals on children. *Biometals* **2019**, *32*, 563–573. [CrossRef]
76. Huang, C.S.; Zhang, L.J.; Meng, J.L.; Yu, Y.J.; Qi, J.Y.; Shen, P.; Li, X.; Ding, P.; Chen, M.B.; Hu, G.C. Characteristics, source apportionment and health risk assessment of heavy metals in urban road dust of the Pearl River Delta, South China. *Ecotoxicol. Environ. Saf.* **2022**, *236*, 113490. [CrossRef]
77. Wu, Z.E.; He, C.; Lyu, H.H.; Ma, X.D.; Dou, X.Y.; Man, Q.L.; Ren, G.B.; Liu, Y.Y.; Zhang, Y.D. Polycyclic aromatic hydrocarbons and polybrominated diphenyl ethers in urban road dust from Tianjin, China: Pollution characteristics, sources and health risk assessment. *Sustain. Cities Soc.* **2022**, *81*, 103847. [CrossRef]
78. Monira, S.; Roychand, R.; Bhuiyan, M.A.; Hai, F.I.; Pramanik, B.K. Identification, classification and quantification of microplastics in road dust and stormwater. *Chemosphere* **2022**, *299*, 134389. [CrossRef]
79. Al-Dousari, A.M.; Alsaleh, A.; Ahmed, M.; Misak, R.; Al-Dousari, N.; Al-Shatti, F.; Elrawi, M.; William, T. Off road vehicle tracks and grazing points in relation to soil compaction and land degradation in Kuwait. *Earth Syst. Environ.* **2019**, *3*, 471–482. [CrossRef]
80. Al-Dousari, A.; Omar, A.; Al-Hemoud, A.; Aba, A.; Alrashedi, M.; Alrawi, M.; Rashki, A.; Petrov, P.; Ahmed, M.; Al-Dousari, N.; et al. A Success Story in Controlling Sand and Dust Storms Hotspots in the Middle East. *Atmosphere* **2022**, *13*, 1335. [CrossRef]
81. Al-Awadhi, J.M.; Al-Dousari, A.; Al-Enezi, A. Barchan dunes in northern Kuwait. *Arab Gulf J. Sci. Res.* **2000**, *18*, 32–40.
82. Ahmed, M.; Al-Dousari, A. Rehabilitation of Artificial Degraded Playa Using PalmMat Water Conservation Techniques. *J. Agric. Sci. Technol.* **2015**, *5*, 90–98. [CrossRef]
83. Zhang, C.; Fang, S. Identifying and Zoning Key Areas of Ecological Restoration for Territory in Resource-Based Cities: A Case Study of Huangshi City, China. *Sustainability* **2021**, *13*, 3931. [CrossRef]
84. Zheng, H.; Zhang, Z.Z.; Xing, X.X.; Hu, T.P.; Qu, C.K.; Chen, W.; Zhang, J.Q. Potentially Toxic Metals in Soil and Dominant Plants from Tonglushan Cu–Fe Deposit, Central China. *Bull. Environ. Contam. Toxicol.* **2019**, *102*, 92–97. [CrossRef] [PubMed]