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Human Health Risk Assessment of Heavy Metals in the Urban Road Dust of Zhengzhou Metropolis, China

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Abstract: The goal of this research is to assess hazardous heavy metal levels in $PM_{2.5}$ fractioned road dust in order to quantify the risk of inhalation and potential health effects. To accomplish this, Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) was used to determine concentrations of eight heavy metals (Cr, Cu, Ni, Zn, Cd, As, Pb, and Hg) in the $PM_{2.5}$ portion of road dust samples from five different land use areas (commercial, residential, industrial, parks, and educational) in Zhengzhou, China. The following were the average heavy metal concentrations in the city: Cr 46.26 mg/kg, Cu 25.13 mg/kg, Ni 12.51 mg/kg, Zn 152.35 mg/kg, Cd 0.56 mg/kg, As 11.53 mg/kg, Pb 52.15 mg/kg, and Hg 0.32 mg/kg. Two pollution indicators, the Pollution Index (PI) and the Geoaccumulation Index (I_{geo}), were used to determine the degree of contamination. Both PI and I_{geo} indicated the extreme pollution of Hg and Cd, while PI also ranked Zn in the extreme polluted range. The US Environmental Protection Agency (USEPA) model for adults and children was used to estimate health risks by inhalation. The results identified non-carcinogenic exposure of children to lead (HI > 0.1) in commercial and industrial areas. Both children and adults in Zhengzhou's commercial, residential, and park areas are exposed to higher levels of copper (Cu), lead (Pb), and zinc (Zn).

Keywords: geo-accumulation index; heavy metals; road dust; inhalation; resuspension; cancer

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1. Introduction

Heavy metals pose a serious threat to human health, and their increasing presence in urban road dust warrants a health emergency. Studies reveal that the accumulation and spread of heavy metals in urban road dust is caused by both anthropogenic and natural factors [1]. Major anthropogenic sources of heavy metals include industrial, household and traffic emissions, while natural sources include soil particle deposition, resuspension, weathering, and erosion [2]. In general, urban areas are more vulnerable to heavy metal contamination compared to rural areas, given the population density and presence of diverse sources of pollution [3]. There has been a worldwide increase in pollutants owing to urban dust, which constitutes a genuine environmental and public health hazard [4].

Environmentalists believe that heavy metal contamination is a significant hazard to the environment [5], and during the previous two decades, a crisis happened with the increasing buildup and spread of heavy metals [6]. There is evidence that chronic deposition of metals in metropolitan environments can operate as a secondary pollution source, resulting in public health issues. Because of their weakened or underdeveloped immune systems, the elderly and children are generally considered the most vulnerable groups. Unintentional intake of road powder, most of which goes from dirty hands to nasal passages, can cause heavy metals to be transferred to the human body [7–9]. Exposure to high amounts of ambient particulates (PMs) can induce severe respiratory effects [10]. In prior research, the respiratory system has been found to be more easily and more seriously affected by $PM_{2.5}$ than other human body systems [11]. Children once again make up the group more susceptible to heavy metals, which can negatively influence their natural growth [12].

The resuspension of dust belonging to the fraction of $PM_{2.5}$ is predominantly a cause of exposure of humans to heavy metals [13,14]. Water-soluble heavy metals have been found to contribute significantly to $PM_{2.5}$ and PM_{10} emissions in a variety of locales, particularly in urban areas [15]. It has been reported in previous research that re-suspended dust is primarily responsible for the presence of PM_1, PM_{10}, and $PM_{2.5}$ fractions. Their traffic emission percentages were found to be 3%, 36%, and 14%, respectively [16]. Moreover, dust particles with sizes < 100 μm can re-suspend due to winds and the movement of vehicles [17]. This kind of resuspension is particularly dangerous as heavy traffic flows do not only move the road dust, but are also responsible for the emission of metals such as Cu, Zn, Fe, and Pb [18]. The situation becomes worse in the case of unmaintained vehicles, not fully meeting the requirements of road-worthiness as is the situation in most of the developing countries. Hence, the production level of $PM_{2.5}$ is increased significantly [19,20].

In urban areas, parks, leisure places, and city squares are the centers of recreational, sporting, and commercial activities. As the living standard and lifestyles in China are improving, people are now more conscious about their health and entertainment, and there is increased anthropogenic activity at such places. Industrial areas are considered even more polluted due to the emission of hazardous gases. So, the health of people who live around these places are affected by the poor quality of environment. The dust containing heavy metals makes its way to the human body through inhalation, resuspension, ingestion, and dermal contact, culminating into serious health issues. That is why it is important to assess and mitigate the pollution levels and their effects on human health.

The main focus of this study is the assessment of health risk caused by $PM_{2.5}$ fraction of road dust. For this purpose, samples were collected from 29 locations that included different functional areas, such as industrial, residential, parks, educational, and commercial areas of Zhengzhou city and the capital of the Henan province in China. The intention behind choosing these areas was to include every prospect of environment where normal human beings come in contact with road dust. In previous studies, mostly the biggest cities received the attention of researchers for road dust pollution analysis, and minor attention was paid to medium or small cities [21,22]. As a result, despite being an economic, educational, industrial, and transportation center in China's central plains, Zhengzhou was overlooked. The key aims of this research, which is concentrated on the Zhengzhou metropolitan area, are as follows: (1) to find out the heavy metal concentrations related to traffic emissions of fraction $PM_{2.5}$ from the road dust of different functional areas; (2) assessment of the pollution degree using pollution indices, and (3) health risk assessment using risk carcinogenic (CR), and Hazard Index (HI) methods for old adults and children [23,24].

2. Materials and Methods

2.1. Study Area Background

As shown in Figure 1, the capital of Henan Province, Zhengzhou (34°45′50.4″ N, 113°41′2.4″ E), located in the megalopolis of the Central Plain, is an important commercial, transport, and logistics hub of central China. The city lies at the foot of the Funiu Mountains on the northeastern side. To the west, it is adjacent to high lands; to the east, it is encompassed by intermediate and lower terrain [25].

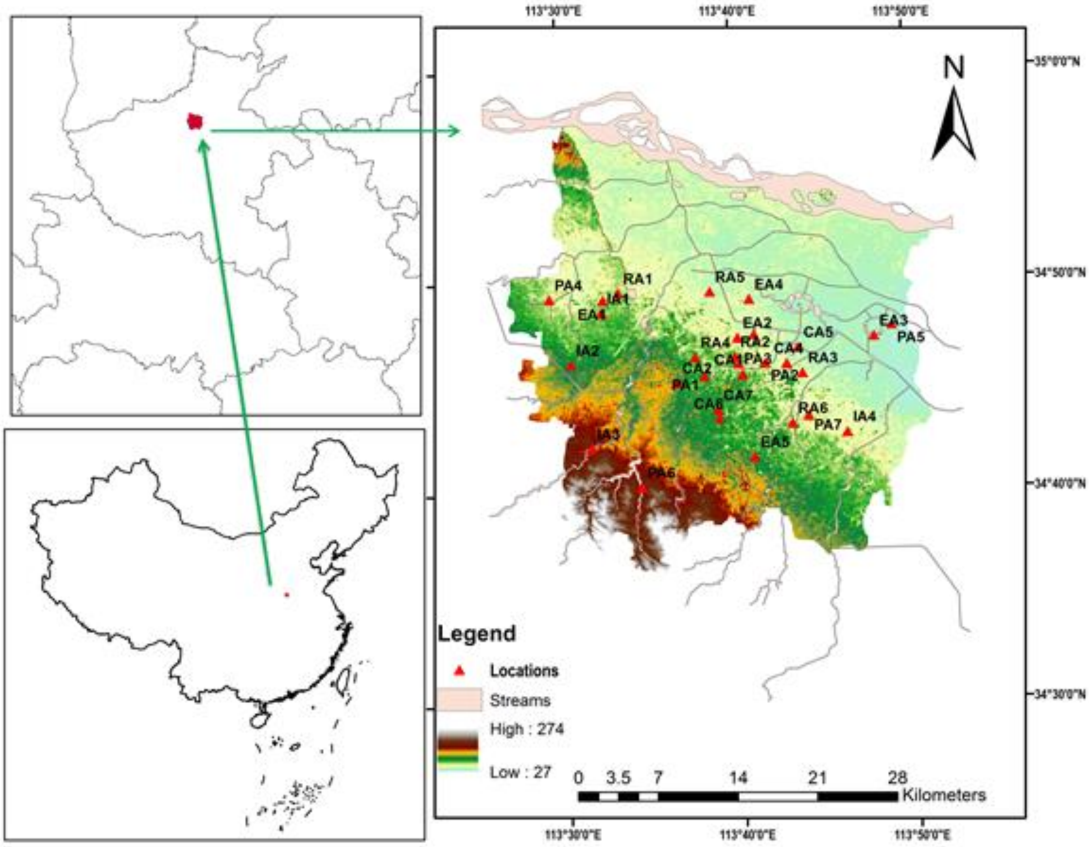

Figure 1. Study Area of Zhengzhou city.

The town has a moderate continental mountain climate in the northern zone. The yearly average temperature is 15.6 degrees Celsius, and the annual average precipitation is 542.15 mm. A monthly average temperature is 25.9 °C in the warmest month of August, while a monthly average temperature was 2.15 °C during the coldest month of January [26]. Despite the fact that there are four different seasons, the summers and winters are of significantly longer durations [27].

Zhengzhou's geographic location, natural resources, cultural glory, political prominence, administrative stature, historical splendor, and significance continue to draw an overwhelming number of visitors and inhabitants. In December 2019, the city's population was anticipated to be 10.350 million people [28]. It was also projected that the city had more than 4,500,000 authorized motor cars [29] and 3,000,000 un-registered automobiles [30]. Each of these features of urbanism contributes to an increase in carbon footprint and the emergence of environmental repercussions that are currently being observed in the city.

2.2. Sampling and Laboratory Analysis

2.2.1. Sample Collection

Twenty-nine locations were selected in Zhengzhou city that cover almost all the important places of different functional nature and the busiest roads, serving the maximum population (adults, patients, and children) of the city, comprising of those directly exposed to road dust pollution. Three samples of road dust were collected from each location: one sample from the center of the road, the second from the side of the road, and the third from the front of building areas near that road. In this way, eighty-seven samples in total were collected from twenty-nine locations, including five educational areas, four industrial areas, six residential areas, seven commercial areas, and seven park/leisure areas. A plastic brush was used to collect the road dust with the help of a pan and then collected into the plastic bags. The quantity of the dust samples was >150 g from one sampling point [31,32].

After that, all the samples were shifted to the laboratory for analysis and kept for at least one week for drying purposes [33].

2.2.2. $PM_{2.5}$ Preparation and Total Metal Concentration

For the preparation of $PM_{2.5}$, Teflon filters were used with a size of 47 mm to acquire the inhalable segment of the $PM_{2.5}$ of road dust [34]. Prior to this process, all the Teflon filters (47 mm) were dried out in a vacuum freeze dryer at 150 °C and kept for 6 h to fully remove the moisture contents, and then were conditioned at 25 °C for next 48 h. Afterwards, using an electronic microbalance, the blank filters were measured thrice and a flask with a size of 250 mL was used to pour road dust with particle sizes <53 µm. The road dust was pushed into the re-suspension chamber with the air pressure after its entry into the flask, and samples of dust were gathered through the outlets of $PM_{2.5}$ on Teflon filters (47 mm) for around a minute [35]. The filters contained $PM_{2.5}$ fractions that were separated from the outlets in the next step. Again, the weight was measured of all the filters thrice using electronic microbalance after the filtration of the $PM_{2.5}$ fraction. At the last step, the filters were folded halfway and stored at 20 °C by wrapping in the foil sheets of aluminum till the analysis was conducted.

Using the same technique employed in prior research studies [36], the total metal content was measured using Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) subsequent aqua-regia digestion with the same approach as per earlier studies. In brief, Teflon filters holding the $PM_{2.5}$ proportion of samples of dust were composed of two equal portions, with each part digested with 5 mL of aqua-regia mixture. In order to analyze the samples using ICP-MS, they were diluted with 2 percent nitric acid (HNO_3) solution and then analyzed using a mass spectrometer.

2.2.3. Quality Control (QC)

In order to ensure the quality of the analysis, all samples were collected in triplicate, including the Standard Reference Material (SRM) and filter blanks. Acids with trace concentrations are deemed appropriate for analysis and digestion. Therefore, we used trace-grade acids (nitric acid and hydrochloric acid) instead of pure acids. The National Center of Standard Materials of China (NCSMC) provided the standard reference material (GBW07451), which was acquired by the institution, i.e., Zhengzhou university (ZZU). The analysis was carried out twice so as to ensure the precision of the spiked samples and aqua-regia digestion process. The recovery percentage was determined using spiked samples, SRM metal concentrations, and samples using the same method as prior studies [36]. The recoveries varied from (90% to 100.3%) and (80% to 130.2%) correspondingly from internal and SRM standards.

2.3. Pollution Level Assessment

The amount of heavy metal contamination in natural environmental samples including dust, soil, and water is determined using a number of methodologies. In this study, Pollution Index (PI) and Geoaccumulation Index (I_{geo}) were used to quantify the pollution degree of heavy metals in $PM_{2.5}$ fractioned road dust samples, and the conclusions were drawn. Because of the log function and constant factor of 1.5, the index of Geoaccumulation differs from various other pollution indices, and thus allows for the prevention of lithogenic effects that may be connected to variations in baseline levels [31]. However, the enrichment factor has been used to distinguish between the roles of natural and manmade sources of pollution [37]. For the purposes of computing the enrichment factor and Geoaccumulation Index, background values of (Cr, Ni, Cu, Zn, As, Cd, Pb, and Hg) in Zhengzhou city were obtained from a previous study [38], that are 64 mg/kg, 21 mg/kg, 14 mg/kg, 42 mg/kg, 8 mg/kg, 0.08 mg/kg, 18 mg/kg and 0.023 mg/kg, respectively.

2.3.1. GeoAccumulation Index (Igeo)

In the following study [39], Geoaccumulation Index (I_{geo}) was used to measure heavy metal pollution in sediments. This approach has been adopted by a large number of researchers for determining the degree of heavy metal pollution in road dust and soil [40–42]. Here is the I_{geo} equation to calculate it:

$$I_{geo} = \log_2 \frac{C_{HM}}{1.5 \times BV} \quad (1)$$

where C_{HM} = heavy metals concentration, BV = background value of metals.

2.3.2. Pollution Index (PI)

The following equation was used to calculate the pollution level that defines the Pollution Index [43]:

$$PI = \frac{C_n}{B_n} \quad (2)$$

where C_n = concentration of metal, B_n = background value of that metal.

Geoaccumulation Index (I_{geo}) and Pollution Index (PI) values and categories were classified in Table 1.

Table 1. Indexes classification for Geoaccumulation Index ($I_{geo)}$ and Pollution Index (PI).

Index	**Value**	**Category**
Geo-accumulation Index (I_{geo})	$I_{geo} < 0$	Unpolluted
	I_{geo} 0–1	Unpolluted–moderately
	I_{geo} 1–2	Moderately
	I_{geo} 2–3	Moderately–strongly
	I_{geo} 3–4	Strongly
	I_{geo} 4–5	Strongly–extremely
	$I_{geo} > 5$	Extremely
Pollution Index (PI)	$PI \leq 1$	Low
	$1 < PI \leq 3$	Medium
	$PI > 3$	High

2.4. Health Risk Assessment

The buildup of hazardous metals in urban road dust has the potential to have a significant adverse effect on human health. By identifying the potential exposure, the level of risk to human health presented by hazardous metals may be quantified [24]. The breathing route has been assigned a significant place among the major routes of heavy metal exposure to human body [44]. The health hazards of $PM_{2.5}$ fractioned road dust samples were examined for old adults and children in this study using a two-step methodology devised by the researchers, which includes risk characterization and exposure assessment [12].

2.4.1. Exposure Assessment

The ongoing research has concentrated exclusively on exposure concentrations and inhalation exposure that were derived using the equation below [23,24].

$$MDI_{inh} = \frac{C \times R_{inh} \times EF \times ED}{PEF \times BW \times AT} \quad (3)$$

where MDI_{inh} = daily average intake dose of metals for inhalation, C = metal concentration, R_{inh} = inhalation rate, EF = exposure frequency, ED = exposure duration, PEF = particular emission factor, BW = body weight, and AT = average time.

2.4.2. Risk Assessment

The Hazards Index (HI), Hazards Quotient (HQ), and Carcinogenic Risk Index (CRI) were used to measure health risks for children and old adults. HQ and HI denote non-carcinogenic risk, but CRI denotes the chances of heavy metals being potentially carcinogenic in old adults and children. These parameters were calculated using the following equations:

$$HQ_i = \frac{MDI}{RFD} \quad (4)$$

$$HI = \sum HQ_i \quad (5)$$

$$CR_i = MDI \times SF \quad (6)$$

$$CR = \sum CR_i \quad (7)$$

where MDI = daily metals intake dose, RFD = reference dose, HQ_i = non-carcinogenic risk, HI = sum of hazard quotient, CR = carcinogenic risk, and SF = slope factor.

3. Results and Discussions

3.1. Heavy Metals in Road Dust

Except for Cr and Ni, all heavy metal mean concentrations were determined to be higher than corresponding background values [38]. The amounts of Hg and Cd were found to be 14 and 7 times higher, respectively, than respective background values. Anthropogenic activity, coal and oil burning, and metal refining can all be attributed for the substantially increased levels of Hg and Cd [45,46]. The mean, median, and minimum and maximum values of heavy metal concentrations are presented in Table 2.

Table 2. Heavy metal statistical values in (mg/kg).

Statistical Values	Cr	Ni	Cu	Zn	As	Cd	Pb	Hg
Background values [38]	64	21	14	42	8	0.08	18	0.02
Min	19.93	6.77	7.99	35.53	8.03	0.12	19.30	0.03
Max	94.78	28.23	63.26	1319.28	17.49	3.48	160.62	1.54
Mean	46.26	12.51	25.13	152.35	11.53	0.56	52.15	0.32
Median	40.96	12.38	22.08	113.45	11.11	0.45	43.16	0.14

The concentration of Zn was the highest among all the heavy metals, but it was lower than that of other major cities of China. Cr, Cu, Ni, Zn, Cd, and Pb concentrations in Zhengzhou were lower than all other cities of China used for the comparison, as presented in Table 3. As and Hg were the only two heavy metals whose concentrations in Zhengzhou were in the intermediate range compared to other cities. Their concentrations in Zhengzhou were higher than those of Beijing but lower than those of Baoji and Guangzhou [47,48]. The concentration of Hg was lower than in Baoji, but higher than in Beijing and Guangzhou [3,48]. In comparison to the background values of Zhengzhou, the concentration was considerably greater, requiring the serious response of regulators and other stakeholders to address the situation. Land use in Zhengzhou's counties had no discernible effect on mercury concentrations. This demonstrates the little effect on the propagation of mercury from road cleaning and sweeping systems and rainfall handling. The heavy metal mean concentrations in the samples were in the following order: Zn > Pb > Cr > Cu >Ni > As > Cd > Hg. It was found that the concentration of heavy metals was maximum in commercial areas, which can be attributed to increased traffic volumes and recreational activities. Additionally, the dense concentration of high-rise structures in a region can impair spontaneous aeration, culminating into increased levels of pollutants [49]. Consequently, the presence of high-rise structures in commercial areas may be responsible for the increased concentration of pollutants. When comparing residential regions to educational and commercial sectors, the zinc concentration was greater in residential areas [50].

The lowest concentrations of heavy metals were found in parks and recreation places, with the exception of As and Cd, which may be related to the distinct behaviors and properties of these metals. For Cr, the maximum concentration was seen in commercial areas, while the lowest concentration was observed in parks. In general, the risk of the presence of toxins was higher in commercial areas. As is evident from the examples of lead and copper, commercial zones had the heaviest loads, whereas parks had the lowest.

Table 3. Comparison of concentrations with other cities of China in (mg/kg).

City	Cr	Ni	Cu	Zn	As	Cd	Pb	Hg
Zhengzhou, China (Background values) [38]	64	21	14	42	8	0.08	18	0.02
Zhengzhou, China (Mean)	46.26	12.51	25.13	152.35	11.53	0.56	52.15	0.32
Beijing, China [3]	92.1	32.47	83.12	280.65	4.88	0.59	60.88	0.16
Beijing Park, China [51]	69.33	25.97	72.13	219.2	-	0.64	201.82	-
Baoji, China [47]	126.7	48.8	123.2	715.3	19.8	NA	433.2	1.1
Chengdu, China [50]	84.3	24.4	100	296	-	1.66	82.3	-
Guangzhou, China [48]	176.22	41.38	192.36	1777.18	20.05	2.14	387.53	0.22
Guiyang, China [52]	129.04	60.43	129.33	176.05	-	0.61	63.12	-
Nanjing, China [21]	126	55.9	123	394	13.4	1.1	103	0.12
Shanghai, China [53]	157	NA	NA	NA	8.73	1.24	246	0.16

The possible source of these heavy metals has been explained in Table 4.

Table 4. Possible sources of heavy metals of this study.

Metals	Possible Emission Source
Cr	Fuel and incineration of lubricants [2]
Ni	Tire abrasion and fuel combustion [54]
Cu	Brake wear, coal combustion, and brake pad [55]
Zn	Brake wear, lubricants, and tire abrasion [56]
Cd	Engine wear, lubricating oil, and brake wear [57]
As	Drinkable water, foods, and tobacco [58]
Pb	Fuel, motor oil combustion, brake wear [18]
Hg	Anthropogenic and natural sources [1]

3.2. Pollution Level Assessment

Numerous approaches for measuring the degree of metal contamination in dust and soil have been proposed. While assessing the degree of accumulation of heavy metals in the $PM_{2.5}$ portion of road dust, we utilized the Geoaccumulation Index (I_{geo}) and the Pollution Index (PI). I_{geo} and PI indices have been deemed well-established techniques for measuring the impacts of heavy metals on the environment by prior research and have been used in a range of applications [41].

3.2.1. Geoaccumulation Index (I_{geo})

Each of the eight metals had their Geoaccumulation Index (I_{geo}) computed, and the results can be seen in Table 5.

Table 5. Heavy metals' Geoaccumulation Index (I_{geo}) in road dust (mg/kg).

Geoaccumulation Index	Cr	Ni	Cu	Zn	As	Cd	Pb	Hg
Minimum	−2.26	−2.21	−1.39	−0.82	−0.57	−0.02	−0.48	−0.02
Maximum	−0.01	−0.15	1.59	4.38	0.54	4.85	2.57	10.02
Mean	−1.14	−1.38	0.07	0.91	−0.08	1.91	0.79	2.71

As per the Geoaccumulation Index (I_{geo}), the exposure of chromium (Cr), arsenic (As), and nickel (Ni) was determined to be minimal and within the range of being unpolluted. They were less than zero in their risk assessment values, demonstrating that the road dust of Zhengzhou was not contaminated with Cr, As, and Ni. Cu, Zn, and Pb contamination values were within the unpolluted to moderately polluted ranges. In the case of Cd and Hg, however, the levels of pollutants, owing to air deposition and road particle absorption, were quite high. The former was determined to be in the moderately contaminated category, whilst the latter was found to be in the moderate to severe polluted range, respectively. In the following order, the Igeo values decreased: Hg > Cd > Zn > Pb > Cu > As > Cr > Ni.

3.2.2. Pollution Index (PI)

The Pollution Index (PI) was computed for each of the eight factors under study, and Table 6 shows the resulting minimum, maximum, and mean values for each of the eight elements under research.

Table 6. Heavy metals' Pollution Index (PI) in road dust (mg/kg).

Pollution Index	Cr	Ni	Cu	Zn	As	Cd	Pb	Hg
Minimum	0.31	0.32	0.65	0.86	1.12	2.19	1.24	1.54
Maximum	1.33	1.08	3.97	16.86	1.81	25.77	5.74	48.12
Mean	0.72	0.59	1.79	3.62	1.43	7.15	2.89	14.25

Chromium (Cr) and nickel (Ni) pollution index values were lower than 1, i.e., 0.72 and 0.59, respectively, which indicated the low pollution or no pollution based on PI estimation. In the case of Copper (Cu), arsenic (As), and lead (Pb), the Pollution Index showed the values 1.79, 1.43, and 2.89, respectively and lies within the range ($1 < PI \leq 3$) of moderate pollution. Zinc (Zn), cadmium (Cd) and mercury (Hg) were in the range ($PI > 3$) of high pollution having values 3.62, 7.15 and 14.25, respectively. So, the concerned heavy metals were Zn, Cd, and Hg as per the Pollution Index (PI) estimation, similar to the Geoaccumulation Index (I_{geo}), with the exception of Zn.

3.3. Health Risk Assessment

For those with weak immune systems, including children and patients, harmful metal-laden road dust can be highly hazardous. Children and adults have inhalation exposure to the heavy metals investigated within $PM_{2.5}$ factionalized road dust samples collected from Zhengzhou. A United States Environmental Protection Agency (USEPA) health risk assessment technique was used to calculate children's and adults' health risks associated with the investigated metals, both non-carcinogenic and carcinogenic. The absence of local guideline values necessitated the use of the USEPA's model to compute health risks. The values from prior literature were used, as indicated in Table 7, to quantify health risks using the model. RFD values were: Cd (1.00×10^{-3}), Cr (2.86×10^{-5}), Cu (4.02×10^{-2}), Ni (2.06×10^{-2}), Pb (3.52×10^{-3}), Zn (3.00×10^{-1}), Hg (8.57×10^{-5}), and As (1.23×10^{-4}), while SF values were; As (1.51×10^{0}), Cd (6.30×10^{0}), Cr (4.20×10^{1}), Ni (8.40×10^{-1}), and Pb (8.50×10^{-3}). A carcinogenic and non-carcinogenic health risk Hazard Index (HI) and Hazard Quotient (HQ) was determined by using MDI_{inh} values for child and adult exposition to toxic metals via resettled road dust. In the current study, eight hazardous metals were chosen for non-carcinogenic and carcinogenic health risk evaluation.

Table 7. Carcinogenic and non-carcinogenic indices parameters.

Parameter	Factor	Values	Units
Average Time	AT	365 × ED	Days
Bodyweight	BW (Child)	15	Kg
Bodyweight	BW (Adult)	70	Kg
Exposure duration	ED (Child)	6	Years
Exposure duration	ED (Adult)	24	Years
Exposure frequency	EF	180	Days/year
Dust inhalation rate	R_{Inh} (Child)	10	m^3/day
Dust inhalation rate	R_{Inh} (Adult)	20	m^3/day
Particular emission rate	PEF	1.36×10^9	m^3/kg

3.3.1. Non-Carcinogenic Risk

The samples of dust collected from distinct land-use areas were used to determine the HI values and HQs in different exposure routes. As per the evaluation made according to statistical data in Table 8, the sequence of the HI values of the all the heavy elements at risk in various functional domains is as follows: commercial > industrial > residential > educational > parks, for adults and children. Although the non-carcinogenic risk score of each heavy element was higher in magnitude for children, compared to those for adults in comparable functional domains, no statistically significant difference was detected between land-use areas. Children in industrial and commercial areas had the highest non-carcinogenic risk level, HI > 0.1, to all the heavy elements exposed to the human body by urban dust in diverse land use. Furthermore, even at low concentrations, lead (Pb) is harmful to human health because it interferes with the development of the brain system and other organs [59]. High amounts of lead in the bloodstream, additionally, can induce bone deformities [60], particularly in youngsters, and may also have a detrimental influence on the body's neurological system, kidneys, and brain tissues [12,52]. The people, particularly youngsters, chronically exposed to polluted commercial and industrial environments require special protection and healthcare. It shows that the HI geographical distribution trend of each heavy element is the same for adults and children. Since children are more vulnerable than adults, the HI for a given heavy element at a given concentration is higher in children than in adults [59]. Arsenic can be present in a variety of sources, including drinkable water, foods, and tobacco. Long-term inorganic arsenic exposure, which is most typically acquired by drinking water and food, has been linked to chronic arsenic poisoning. As per a World Health Organization study, arsenic in contaminated water is easily absorbed and might cause health problems based on its metabolic form [58].

Table 8. Hazard Index (HI) values of heavy metals in different land use areas.

		HI							
Land Use Areas	Non-Carcinogenic	Cr	Ni	Cu	Zn	As	Cd	Pb	Hg
Educational	Adult	9.12×10^{-3}	1.83×10^{-4}	4.07×10^{-4}	3.66×10^{4}	1.06×10^{-2}	9.90×10^{-4}	9.79×10^{-3}	1.03×10^{-2}
	Children	1.71×10^{-2}	4.15×10^{-4}	3.82×10^{-3}	3.41×10^{-3}	2.42×10^{-2}	1.75×10^{-3}	9.07×10^{-2}	1.04×10^{-2}
Residential	Adult	1.18×10^{-2}	1.86×10^{-4}	5.66×10^{-4}	3.92×10^{-4}	1.04×10^{-2}	5.80×10^{-4}	1.05×10^{-2}	1.56×10^{-2}
	Children	2.13×10^{-2}	4.15×10^{-4}	5.29×10^{-3}	3.65×10^{-3}	2.32×10^{-2}	1.02×10^{-3}	9.64×10^{-2}	1.54×10^{-2}
Parks	Adult	8.41×10^{-3}	1.64×10^{-4}	2.88×10^{-4}	2.25×10^{-4}	1.06×10^{-2}	5.41×10^{-4}	7.11×10^{-3}	7.96×10^{-3}
	Children	1.54×10^{-2}	3.67×10^{-4}	2.67×10^{-3}	2.08×10^{-3}	2.43×10^{-2}	9.58×10^{-4}	6.59×10^{-2}	7.87×10^{-3}
Commercial	Adult	1.56×10^{-1}	1.87×10^{-4}	7.44×10^{-4}	3.46×10^{-4}	9.22×10^{-3}	8.43×10^{-4}	1.36×10^{-2}	1.61×10^{-2}
	Children	2.85×10^{-2}	4.16×10^{-4}	6.93×10^{-3}	3.25×10^{-3}	2.08×10^{-2}	1.51×10^{-3}	1.25×10^{-1}	1.59×10^{-3}
Industrial	Adult	1.65×10^{-2}	2.81×10^{-4}	3.32×10^{-4}	3.17×10^{-4}	9.72×10^{-3}	5.16×10^{-4}	1.17×10^{-2}	9.77×10^{-3}
	Children	3.07×10^{-2}	6.32×10^{-4}	3.06×10^{-3}	2.92×10^{-3}	2.21×10^{-2}	9.11×10^{-4}	1.06×10^{-1}	9.64×10^{-3}

3.3.2. Carcinogenic Risk

The carcinogenic risk of heavy metals such as Cr, Ni, Cd, and As assessed in this study revealed that the risk of cancer for Ni, Cd, and As was negligible, with average cancer risk factors of 6.57×10^{-10}, 2.03×10^{-10}, and 9.66×10^{-10}, correspondingly, which fell below the lower range of threshold values 10^{-6} to 10^{-4} and are considered acceptable, as shown in Table 9. However, the higher value of As was a cause for concern and can lead to many harmful consequences such as severe damage (keratosis, leucomelanosis, and melanosis) [61]. In Zhengzhou, the cancer risk (Cr = 1.16×10^{-7}) posed to the population was possibly near to the lower limit value of 10^{-6}, while the samples collected from inside the industrial region exhibited a cancer risk of 8.57×10^{-7}. Carcinogenic elements are classified into five functional categories based on their hazard index values. The largest cancer health hazards are associated with Cr and Ni and are found in the industrial region, followed by commercial, residential or educational, and parks, which have comparable HI values. Furthermore, chromium is widely used to preserve metal surfaces and construction materials, including in electrolysis, cells, polymers, and fertilizers [50]. Thus, the development of educational and commercial buildings, as well as the usage of cells and polymers in residential areas, may account for the educational, commercial, and residential areas having higher carcinogenic values of chromium (Cr). As a result, the cancer risk associated with Cr exposure to people, particularly in industrial settings, should be given significant consideration. A comprehensive assessment of pollution risks for a city should also consider the health risks posed by certain toxins, such as polycyclic aromatic hydrocarbons ($PM_{2.5}$), other undetected heavy metals including Fe and Mn, or in somewhat high-pollution areas (such as mining areas), in addition to the risks posed by other pollutants.

Table 9. Carcinogenic Risk (CR) values of heavy metals in different land use areas.

		CR			
Land Use Areas	**Carcinogenic**	**Cr**	**Ni**	**As**	**Cd**
Educational	Adult	8.93×10^{-8}	6.31×10^{-10}	1.02×10^{-9}	2.90×10^{-10}
Residential	Adult	1.12×10^{-7}	6.25×10^{-10}	9.77×10^{-10}	1.71×10^{-10}
Parks	Adult	8.21×10^{-8}	5.55×10^{-10}	1.04×10^{-9}	1.60×10^{-10}
Commercial	Adult	1.53×10^{-7}	6.33×10^{-10}	8.86×10^{-10}	2.46×10^{-10}
Industrial	Adult	1.60×10^{-7}	9.61×10^{-10}	9.31×10^{-10}	1.50×10^{-10}

4. Conclusions

Heavy chemicals in road dust pose a serious health risk to people. The amounts of eight heavy metals in Zhengzhou metropolitan road dust and the level of harm to human health have been evaluated in the current study. With the exception of Ni and Cr, all heavy metal concentrations were determined to be greater than their background levels. The amounts of Hg and Cd were 14 and 7 times greater than their respective background levels, which shows high contamination. This alarming situation requires immediate action by all stakeholders. I_{geo} indicated a range of pollution categories, from strongly polluted (Cd and Hg) to unpolluted (Ni and Cr). PI produced almost similar results, placing Ni and Cr in the range of low pollution or no pollution and Cd, Zn, and Hg in the range of high pollution, whereas Zn pollution was not indicated by Igeo.

Analyzing non-carcinogenic risk factors, the largest for children was the exposure to Pb (HI > 0.1) in commercial and industrial areas among all the land-use areas under consideration. It was further divulged that that both children and adults in Zhengzhou's commercial, residential, and park areas were highly exposed to Cu, Pb, and Zn. The major source of these metals in such cases is vehicular exhaust. Northwestern Zhengzhou was found at the highest non-carcinogenic exposure risk to Cr and Ni from point sources. The cancer risk value of Cr was more likely to be at the lower limit of the threshold value, particularly in the industrial sector. As a result of the enhanced heavy metal concentrations in road dust as compared to background levels, it appears that the current situation is deteriorating, and people of the Zhengzhou metropolitan are at high risk of experiencing to these heavy metals.

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