atmosphere

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Risk Assessment of the Impact of Heavy Metals in Urban Traffic Dust on Human Health

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Abstract: Excessive exposure to heavy metals induces potential adverse health impacts in humans. More specifically, heavy metals in particulate matter (PM) have a significant impact since PM can penetrate human organs and systems, causing several morbidities. In this work, dust samples were collected from 20 different types of roads in a busy zone in Doha during the winter of 2016–2017, where a higher human exposure rate occurs due to extensive outdoor activities during this time of the year. The elemental composition in terms of the mass concentration of 30 elements was determined in each sample via an energy-dispersive X-ray fluorescence (XRF) spectrometer. Then, the toxicity of six heavy metals in these airborne traffic dust samples was investigated. The heavy metals reported to have a hazardous impact on human health are As, Pb, Hg, Cd, Cr, Co, Ni, Cu, and Zn. The extent of carcinogenic and non-carcinogenic risk impact was assessed using pollution indices and then determining the health risks associated with exposure to heavy metals through inhalation, ingestion, and dermal contact. The non-carcinogenic hazard index analysis results indicate no toxicity for all metals. However, the carcinogenic risk factor results show that only chromium might induce a slight risk for children and adults. In light of this, further research is recommended to investigate more areas in urban Doha where more samples can be collected and analyzed.

Keywords: heavy metals; toxicity; risk assessment; health impact; traffic emissions; Qatar

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Citation: Mahmoud, N.; Al-Shahwani, D.; Al-Thani, H.; Isaifan, R.J. Risk Assessment of the Impact of Heavy Metals in Urban Traffic Dust on Human Health. *Atmosphere* **2023**, *14*, 1049. https://doi.org/10.3390/atmos14061049

Academic Editors: Elena Hristova, Manousos Ioannis Manousakas, Anikó Angyal and Maria Gini

Received: 9 May 2023
Revised: 8 June 2023
Accepted: 12 June 2023
Published: 19 June 2023

1. Introduction

The accumulation of heavy metals in the environment due to human activities can become hazardous to living organisms [1,2]. Moreover, anthropogenic sources of heavy metals have a critical impact on human health. Most airborne heavy metals are released into the environment through different processes that involve fossil fuel burning, such as industrial, mining, and smelting activities [3]. Industrial activities generate mercury, lead, cadmium, chromium, cobalt, nickel, copper, zinc, and arsenic. Chromium is mainly produced in the ferrochrome industry and from chromate production in the form of hexavalent chromium [3]. Nickel dust fumes are generated through nickel alloy production, in which inhalation is the main route of exposure. However, traffic pollution, specifically particulate matter emissions, has attracted increased attention worldwide since it has impacted urban areas and the health of residents in crowded cities [4].

In a global index of countries with record economic growth over the past 20 years, Qatar has come out on top due to its wealth derived from oil and gas resources. These exceptional developments have been accompanied by heavy traffic and industrial operations [5]. According to the Fédération internationale de football association (FIFA) dust management research in Qatar, Qatar has significant quantities of particulate matter, primarily due to the dry climate, and readily transported fine particulates from the desert contaminate the air and harm people's health when they enter cities and towns [6]. Furthermore, the country is rapidly developing, necessitating construction work and heavy traffic, which adds to air pollution [4]. To the best of our knowledge, no studies about the effects of heavy metals on human health have been carried out in Qatar. Additionally, based on accepted standards, there are no studies about how the reported heavy metals of traffic dust are associated with health effects, particularly in humans.

Particulate matter (PM) is an air pollutant that poses a high risk to human health since fine particles can penetrate deep into human organs, causing irritation and long-term damage [7]. PM toxicity mainly depends on particle size, chemical composition, and particle characteristics [7,8]. Among several constituents of PM, heavy metals were found to be part of the chemical composition of PM regardless of their sources, which means they travel through the atmosphere easily [9]. PM's toxicity and harmful effects on human health depend mainly on the type of heavy metals adsorbed to PM surfaces [8]. Moreover, when heavy metals' concentration exceeds the permissible limits, they become toxic to humans, causing several short- and long-term morbidities, including cancer [3]. The harmful effects associated with high concentrations of heavy metals have been increasing due to increased human anthropogenic activities. Each element of heavy metals induces distinct toxicities since the adverse health effects are distinctive in relation to the exposure routes of the toxicant [3]. Heavy metal toxicity targets different organs and systems in the human body, such as the kidneys, liver, heart, skin, nervous system, reproduction, and immune responses. In addition, some heavy metals induce carcinogenicity and genotoxicity [3].

Heavy metals' toxic effects through inhalation routes are slightly different compared with other routes of exposure. For instance, the main harmful effects of mercury by inhalation are neurotoxicity and renal toxicity, but it also affects the kidneys and the thyroid [10]. Furthermore, chronic exposure to mercury-contaminated air affects the central nervous system and kidneys [11]. Chromium in its hexavalent form is carcinogenic and genotoxic, specifically to lung tissues. Other effects due to chromium exposure include pulmonary and heart-related toxicity [3]. The nickel exposure route is mainly inhalation; therefore, its carcinogenic effect includes several epigenetic effects in addition to the evolution of lung and nasal cancers [11]. Moreover, its noncarcinogenic effects include dermatitis, gastrointestinal manifestation, lung fibrosis, and cardiovascular diseases [11]. The inhalation of arsenic causes cardiovascular disease and respiratory cancer [2]. Cadmium is carcinogenic and damages the kidneys and bone when exposed to it for long periods. However, acute exposure has a detrimental effect on the respiratory system [12,13]. Long-term exposure to cobalt induces respiratory system distress, such as asthma, while chronic exposure might cause cancer when combined with tungsten carbide [14].

All the above-listed risks become more intense when the susceptible population is children, adults, people with weak immunity, and pregnant women, who are more likely to experience disease severity [15]. Children and other young adults are especially vulnerable because of high amounts absorbed across the gastrointestinal system, which also involves rapid cell metabolism. Children are more affected if they are exposed to deficient levels compared to healthy adults, who might have fewer unhealthy consequences [16]. In pregnant women who have a high probability of a miscarriage, stillbirth, or giving birth to a child with a birth defect, these probabilities could all be increased by exposure to heavy metals. These metals may also impact fetal brain growth [17]. The neuro-developmental consequences of lead exposure in children are one of its significant effects on human health. Children between the age of 0 and 5 years old who are exposed to very low amounts of lead may experience developmental effects and subsequently have lower IQs [18]. Children's activities and behavior, especially "pica" behavior in which young children accidentally or purposefully consume large amounts of soil, can increase children's exposure above that of adults in the same environment [19]. Moreover, the exposure of pregnant women to lead causes a significant risk as it crosses the placental barrier during pregnancy, inducing growth impacts on the embryo in the uterus [20].

This work uses the elemental composition of PM traffic emissions in terms of heavy metal concentrations to report on the first study to assess the toxicological effect of heavy metals in traffic-borne air pollution samples in Doha. Initially, 30 elements were measured; however, 9 elements were used for the health impact assessment in agreement with what has been reported earlier, as these are known to pose risks to human health. The hazard index of six out of the nine measured heavy metals on human health was estimated, since three metals were found to be of negligible concentration in the samples. The extent of impact was assessed using pollution indices, and then the associated health risks were determined using carcinogenic risk (CR) and hazard index (HI) methods for children and adults.

2. Materials and Methods

2.1. Study Area and Sample Collection

As per the previous work, dust samples were collected, and XRF in situ measurements were taken on 20 side and main roads in a busy zone in Doha (zone 51) [4]. In brief, dust was left to fall and accumulate on clean glass holders and was collected monthly between December 2016 and February 2017. The average temperature in those months is around 20 °C, and the weather is mild and sunny. The sampling locations reflect busy roads with heavy traffic and side roads with less traffic frequency, as reported in [4].

2.2. Sample Analysis

The samples were characterized in terms of particle size distribution, chemical composition, acidity, and enrichment factor calculations, as reported in [4]. The size distribution was obtained via an optical microscope where optical images were taken, and the particle size of about 300 particles was measured in each image. The results indicate that most PM in these samples is fine ($PM_{2.5}$), with a particle size range of 1.2 to 600 µm, indicating a high risk to human health upon short- and long-term exposure. The chemical composition was analyzed via an SEM/EDS model JCM-6000PLUS NeoScope Benchtop. The acidity of the sample was measured following a standard method. The elemental composition in terms of the mass concentration of 30 elements (Mg, Al, Si, S, Cl, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, As, Sr, Zr, Pb, P, Rb, Sn, V, K, Ag, Rh, Tl, Ta, Hf, Ce, Ba, and Mo) was determined in each sample via a Bruker S1 Titan (Bruker, USA) handheld energy-dispersive X-ray fluorescence (XRF) spectrometer. The mass concentration of the heavy metals ranged from around 18 for As to about 151 mg/Kg for Zn. The enrichment factor was calculated, considering Al as the reference element [4].

2.3. Contamination Assessment

2.3.1. Geo-Accumulation Index

The contamination of urban dust was assessed using the geo-accumulation index (I_{geo}), proposed by Muller in 1969 [21]. It provides the level of soil contamination for each element. Samples were evaluated using the following equation:

$$I_{geo} = log_2\left(\frac{Cn}{1.5Bn}\right) \tag{1}$$

where Cn is the dust sample concentration and Bn is the background concentration value of the element, both in mg/kg. The background value in this study was obtained from the Alshahaniya area in Qatar as a reference value from an area distant from urban traffic and known for its natural dust resources. The background values for As, Pb, Cr, Ni, Cu, and Zn were 0 (mg/kg), 0 (mg/kg), 0 (mg/kg), 10.33 (mg/kg), 79 (mg/kg), and 13.5 (mg/kg), respectively. However, these values were multiplied by a constant of 1.5 to allow for the correction of background values due to lithological variability [12]. The level of contamination is categorized as seen in Table 1.

Table 1. Categories of the value of the geo-accumulation index [21].

Value	Class	Contamination Level
$I_{geo} \leq 0$	Class 0	Uncontaminated
$0 < I_{geo} \leq 1$	Class 1	Uncontaminated to moderately contaminated

Table 1. *Cont.*

Value	Class	Contamination Level
$1 < I_{geo} \leq 2$	Class 2	Moderately contaminated
$2 < I_{geo} \leq 3$	Class 3	Moderately to highly contaminated
$3 < I_{geo} \leq 4$	Class 4	Highly contaminated
$4 < I_{geo} \leq 5$	Class 5	Highly to very highly contaminated
$I_{geo} \geq 5$	Class 6	Very highly contaminated

Urban soil contamination was assessed through the pollution index method, which evaluates the risk associated with each element. Then, the integrated pollution index (PI_i), as described by Tomlinson et al., was used [22], with the classification shown in Table 2 [23]. The background concentrations of the studied metals were obtained from the Alshahaniya area as per the values mentioned above. Each heavy metal element was assessed as per the following equations:

$$PI_i = \frac{Ci}{Bi} \tag{2}$$

$$IPI_i = (IP_1 + IP_2 + IP_3 + \cdots + IP_n)/n \tag{3}$$

where PI_i is the pollution index of element i in urban dust, Ci is the concentration of heavy metals i (mg/kg), and Bi is the background value of element i.

Table 2. Categories of the value of pollution index [22].

Value	Pollution Level
$IPI \leq 1$	Low level
$1 < IPI \leq 2$	Moderate level
$2 < IPI \leq 5$	High level
$5 < IPI$	Extremely high level

2.3.2. Health Risk Assessment

Health risk assessment is a method proposed by the United States Environmental Protection Agency (US EPA) to evaluate human health risks triggered by exposure to chemical toxicants [24]. Humans are generally exposed to toxicants through three routes: inhalation, dermal contact, and ingestion. The heavy metals considered in the health risk assessment in this work are As, Pb, Cr, Ni, Cu, and Zn, as shown in Table 3. Other heavy metals, including mercury, cadmium, and cobalt, were considered, but their concentration was too low to be detected.

The following equations can be used to calculate the long-term daily average exposures of the three mentioned exposure pathways and the exposure to carcinogenic heavy metals [25]:

$$ADD_{ing} = \frac{\mathrm{c} \times \mathrm{R_{ing}} \times \mathrm{CF} \times \mathrm{ED}}{\mathrm{BW} \times \mathrm{AT}} \tag{4}$$

$$ADD_{inh} = \frac{\mathrm{c} \times \mathrm{R_{inh}} \times \mathrm{EF} \times \mathrm{ED}}{\mathrm{PEF} \times \mathrm{BW} \times \mathrm{AT}} \tag{5}$$

$$ADD_{derm} = \frac{\mathrm{c} \times \mathrm{SA} \times \mathrm{CF} \times \mathrm{SL} \times \mathrm{ABS} \times \mathrm{ED}}{\mathrm{BW} \times \mathrm{AT}} \tag{6}$$

where ADD_{ing}, ADD_{inh}, and ADD_{derm} (mg/(kg day)) are ingestion, respiratory, and dermal intake, respectively. c is the concentration of heavy metals in street dust measured in (mg/kg). ED (year) is the duration of exposure (years). CF is a conversion factor, as shown in Table 4. EF is the exposure frequency (day/year). The rate of human ingestion (R_{ing}) and inhalation (R_{inh}) of air-containing dust is measured in m^3/day. SA is the surface area of a person's dust exposure, measured in square centimeters (cm^2); the dermal adherence and absorption factors are AF and ABS, respectively. BW is the average body weight of those exposed (kg), PET is the particle emission factor (m^3/kg), and AT is the average time of exposure (days) [26]. Table 4 shows a summary of the parameters used in this work.

Table 3. The in situ measured average concentrations of the elements investigated in this work.

Elements	Concentration in Urban Doha	Background Concentration
	(mg/kg)	
Arsenic (As)	18.86	0
Lead (Pb)	63.28	0
Mercury (Hg)	0	0
Cadmium (Cd)	0	0
Chromium (Cr)	60.31	0
Cobalt (Co)	0	0
Nickle (Ni)	31.28	10.33
Copper (Cu)	56	79
Zinc (Zn)	151.37	13.5

Table 4. Summary of the parameters used in the health impact assessment calculations in this work.

Parameter	Unit	Child	Adult	References
Concentration of element (C)	mg/kg	As per Table 3		This study
Body weight (BW)	kg	15	70	[27]
Exposure frequency (EF)	days/year	180	180	[28]
Exposure duration (ED)	years	6	24	[26]
Ingestion rate (R_{ing})	mg/day	200	100	[24,28]
Inhalation rate (R_{inh})	m^3/day	10	20	[29]
Skin surface area (SA)	cm^2	2800	5700	[28]
Soil adherence factor (SL)	mg/cm^2·day	0.2	0.07	[28]
Dermal absorption factor (ABS)	None 0.03 for Arsenic 0.001 for all other metals			[30]
Particulate emission factor (PEF)	m^3/kg	1.36×10^9	1.36×10^9	[28]
Conversion factor (CF)	kg/mg	1×10^{-6}	1×10^{-6}	[31]
Average time (AT):				
for carcinogens	days	365 × 70	365 × 70	[28]
for non-carcinogens		365 × ED	365 × ED	[27]

Non-carcinogenic risk can be calculated using the *HI*, which is expressed as follows:

$$HI = \sum HQi \tag{7}$$

$$HQ = \frac{ADD}{RfD} \tag{8}$$

where *ADD* (mg/(kg day)) is the daily average exposure dose, *RfD* (mg/(kg day)) is the daily reference dose of the contaminant ingested through an exposure route. *HI* is the hazard index, and HQ is the hazard quotient for the various metals involved in the health risk analysis. If the HQ or HI value is less than one, the risk is considered negligible; if the value is greater than one, the non-carcinogenic risk is considered significant [26].

The cancer risk was evaluated for As, Cr, and Pb as they are classified as carcinogenic elements, according to the International Agency for Research of Cancer (IARC). Cancer risk is measured using the following equation:

$$Cancer\ risk\ (CR) = ADD \times SF \tag{9}$$

CR is the chance of developing cancer, and SF (mg/(kg day)) is the carcinogenic slope factor, with the reference values given in Table 5. The permissible levels of cancer risk values are between 10^{-4} and 10^{-6}. A CR value over 10^{-4} is considered detrimental [32].

Table 5. Reference slope factor values for cancer risk analysis [33,34].

Element	SF_{ing} (mg/(kg day))	SF_{inh} (mg/(kg day))	SF_{derm} (mg/(kg day))
As	1.5	1.51	3.66
Pb	0.0085	0.042	-
Cr	0.05	4.20	2.00
Ni	1.70	0.9	4.25

3. Results and Discussions

3.1. Contamination Assessment

The assessed geo-accumulation indices in this work were 1.01, −1.08, and 2.89 for Ni, Cu, and Zn, respectively, as shown in Table 6. These results indicate that the I_{geo} values for Ni and Zn belong to class 1 and class 3, respectively. This means that the samples are moderately to heavily contaminated with respect to Zn, while they are uncontaminated to moderately contaminated with respect to Ni.

Table 6. The I_{geo}, PI, and IPI values of urban dust samples.

Indices	Ni	Classification	Cu	Classification	Zn	Classification
I_{geo}	1.01	Uncontaminated to moderate contamination	−1.08	Uncontaminated	2.89	Moderate to heavy contamination
PI	3.02	High pollution	0.71	Low pollution	11.2	Extremely high pollution
IPI		4.98			High pollution	

However, As, Pb, and Cr were not assessed due to background concentration being below the detection limit. Moreover, the urban dust samples were not contaminated with Cu since the I_{geo} value falls into class 0. Hou et al. (2019) [35] suggested that traffic emissions are the primary source of heavy metal contamination of road dust. More specifically, they found that the spatial distribution of health risks indicated that the health risks are more severe in southeast China than in the northwest due to the impact of traffic emissions, which were marked by Cu, Zn, Cd, and Pb in street dust [35]. Another study found that tires have a high Zn concentration, possibly due to tire lubricants [36]. Moreover, Ferreira et al. investigated the risk assessment of street dust in Angola. They found that the highest levels of risk were associated with the presence of As and Pb in the street dust and with the route of ingesting dust particles in that area [30]. It is worth noting that the study area consists of many road junctions to minimize traffic load; however, during rush hours, road junctions become heavily jammed with vehicles, increasing the concentration of heavy metals on the road and subsequently contaminating dust particles.

According to the results in Table 6, the heavy metals were ranked in the following order: Zn > Ni > Cu. It can be seen that Zn has the highest pollution index at a value of 11.2, which indicates that Qatar's urban dust is highly contaminated. The reason Zn is high is due to vehicle emissions, as well as the mechanical components and tires of moving cars that are abraded, which are a potential source of zinc [37]. Additionally, Ni is in the moderate contamination range due to roadside and industrial areas. However, Cu has no contamination effect in the samples investigated in this work. The IPI, defined as the mean PI value for all heavy metals, is another frequently used criterion to assess heavy metal pollution in soils. The IPI is low when it is less than 1, $1 < \text{IPI} \leq 2$ indicates moderate levels, $2 < \text{IPI} \leq$ indicates high levels, and IPI > 5 indicates extremely high levels of pollution. The result of the IPI suggests a high pollution level (IPI = 4.9). This demonstrates how the road traffic environment has impacted the Doha region.

3.2. Non-Carcinogenic Risk

Tables 7 and 8 show the HQ and HI for As, Pb, Cr, Ni, Cu, and Zn for adults and children. The results show that HQ values of heavy metals in urban dust are greater than 1, suggesting that heavy metals induce negative health impacts on residents through ingestion, inhalation, and dermal contact with urban dust. This can possibly result in gastrointestinal system irritation, hypertension, nausea, vomiting, eczema, asthma, insomnia, diarrhea, and anemia. It can also possibly cause miscarriage in females and lead to brain and central nervous system development defects in children [38]. Based on the values of the HI for adults and children, the ingestion route of contamination was found to have the highest health risk, followed by inhalation and dermal contact. The estimated total HI values of heavy metals for adults and children were all below the value recommended by the USEPA, which is less than 1. Furthermore, the results indicate that adults and children in Doha are exposed to possible non-carcinogenic health hazards. The decreasing order of the hazardous index of heavy metals for adults was found to be As > Cr > Pb > Ni > Cu > Zn. However, for children, the HI decreasing order was found to be As > Pb > Cr > Ni > Cu > Zn. Furthermore, the results in Table 8 indicate that children are more prone to developing health issues than adults, and similar findings were reported by Suvetha et al. in the city of Tiruchirappalli in South India [39]. Children are expected to be more at risk than adults since they have certain behavioral habits, such as hand-to-mouth behavior, higher respiration rate, and strong gastrointestinal adsorption [40,41].

Table 7. Results of HQ and HI of heavy metal for adults.

Elements	RfD_{ing} (mg/kg day)	RfD_{inh} (mg/kg day)	RfD_{derm} (mg/kg day)	HQ_{ing}	HQ_{inh}	HQ_{derm}	HI
As	3.00×10^{-4}	1.23×10^{-4}	1.23×10^{-4}	2.30×10^{-3}	2.82×10^{-5}	1.65×10^{-4}	4.67×10^{-4}
Pb	1.40×10^{-3}	3.52×10^{-3}	5.24×10^{-4}	1.65×10^{-3}	3.30×10^{-6}	8.80×10^{-6}	1.84×10^{-4}
Cr	3.00×10^{-3}	2.86×10^{-5}	3.00×10^{-3}	7.34×10^{-4}	3.87×10^{-4}	1.47×10^{-6}	2.98×10^{-4}
Ni	2.00×10^{-2}	2.06×10^{-2}	5.40×10^{-3}	5.71×10^{-5}	2.79×10^{-7}	4.22×10^{-7}	6.54×10^{-6}
Cu	4.00×10^{-2}	4.00×10^{-2}	1.20×10^{-2}	5.11×10^{-5}	2.57×10^{-7}	3.40×10^{-7}	5.83×10^{-6}
Zn	3.00×10^{-1}	3.00×10^{-1}	6.00×10^{-2}	1.84×10^{-5}	9.27×10^{-8}	1.84×10^{-7}	2.14×10^{-6}
Total	-	-	-	-	-	-	9.64×10^{-4}

Table 8. RfD, HQ, and HI of heavy metals for children.

Elements	RfD_{ing} (mg/kg day)	RfD_{inh} (mg/kg day)	RfD_{derm} (mg/kg day)	HQ_{ing}	HQ_{inh}	HQ_{derm}	HI
As	3.00×10^{-4}	1.23×10^{-4}	1.23×10^{-4}	2.30×10^{-3}	2.82×10^{-5}	1.65×10^{-4}	2.49×10^{-3}
Pb	1.40×10^{-3}	3.52×10^{-3}	5.24×10^{-4}	1.65×10^{-3}	3.30×10^{-6}	8.80×10^{-6}	1.66×10^{-3}

Table 8. *Cont.*

Elements	RfD_{ing} (mg/kg day)	RfD_{inh} (mg/kg day)	RfD_{derm} (mg/kg day)	HQ_{ing}	HQ_{inh}	HQ_{derm}	HI
Cr	3.00×10^{-3}	2.86×10^{-5}	3.00×10^{-3}	7.34×10^{-4}	3.87×10^{-4}	1.47×10^{-6}	1.12×10^{-3}
Ni	2.00×10^{-2}	2.06×10^{-2}	5.40×10^{-3}	5.71×10^{-5}	2.79×10^{-7}	4.22×10^{-7}	5.78×10^{-5}
Cu	4.00×10^{-2}	4.00×10^{-2}	1.20×10^{-2}	5.11×10^{-5}	2.57×10^{-7}	3.40×10^{-7}	5.17×10^{-5}
Zn	3.00×10^{-1}	3.00×10^{-1}	6.00×10^{-2}	1.84×10^{-5}	9.27×10^{-8}	1.84×10^{-7}	1.87×10^{-5}
Total	-	-	-	-	-	-	5.40×10^{-3}

3.3. Carcinogenic Risk

Daily intake of heavy metals determines their toxicity to the human body [42]. The excess lifetime of cancer risk (CR) for children and adults was calculated for the three exposure pathways (inhalation, dermal, and ingestion) for the contribution of an average heavy metal in the air.

According to the International Agency for Research on Cancer (IRAC), As, Ni, and Cr (VI) have been classified as group 1 carcinogens, while Pb is classified as a group 2A carcinogen. Hence, based on the results of this work, most of the CR values for the investigated heavy metals fall within the acceptable range of risk level (10^{-4}–10^{-6}), except Cr. Hence, since the values are generally less than 10^{-6}, this indicates that there is a low risk of cancer.

CRs for adults and children were calculated using the inhalation, dermal, and ingestion of ADD and multiplying the obtained values with a slope factor (SF) to obtain the CR, as presented in Table 9.

Table 9. Cancer risk values through ingestion, inhalation, and dermal exposure to urban dust samples.

Elements	CR_{ing} Adult	CR_{ing} Child	CR_{inh} Adult	CR_{inh} Child	CR_{derm} Adult	CR_{derm} Child
As	3.80×10^{-8}	8.86×10^{-8}	1.01×10^{-9}	4.48×10^{-10}	3.17×10^{-8}	6.35×10^{-9}
Pb	7.21×10^{-10}	1.68×10^{-9}	9.44×10^{-11}	4.18×10^{-11}	-	-
Cr	4.05×10^{-6}	9.44×10^{-6}	9.00×10^{-9}	3.99×10^{-9}	1.85×10^{-9}	3.88×10^{-10}
Ni	7.14×10^{-8}	1.67×10^{-7}	1.00×10^{-9}	4.43×10^{-10}	2.03×10^{-9}	4.08×10^{-10}

The results show that adults' and children's CRs in three of the exposure categories do not exceed the 1×10^{-6} limit, except for Cr via ingestion. These low values indicate that there is no to very low cancer risk. The inhalation route has the least cancer risk of all, with Pb having the lowest value of 9.44×10^{-11} and 4.18×10^{-11} for adults and children, respectively. At the same time, the ingestion route has the highest, with Cr reaching up to 4.05×10^{-6} and Cr 9.44×10^{-6} for adults and children, respectively. Chromium has the highest cancer risk from ingestion, followed by Ni, As, and Pb in children, while adults were found in the descending order Cr > As > Ni > Pb, and all of the elements have low CRs. Pb has the lowest carcinogenic effects in children, cannot cause cancer in adults or children, and is considered a group 2A carcinogen. However, it has been reported that children have a higher risk of exposure to heavy metals and lower tolerance to pollutants than adults due to their lower body weight. Hence, children have a higher carcinogenic risk [43]. However, the source of pollutants is required to identify the metal's emission source for further management and emission control actions [4,5].

4. Conclusions

The evaluation of the health risk of exposure to heavy metals in urban traffic dust provided insights into the quality of dust and the environment in relation to the level of toxicity in Doha. The pollution level of heavy metals in Doha city was estimated using I_{geo} and IPI. I_{geo} was found to have been moderately to heavily contaminated, except for Cu. On the other hand, the IPI indicated a high pollution level, with Zn being the most abundant pollutant. Despite the HQ and HI values for both children and adults varying, the risk assessment for each metal revealed the same patterns. Heavy metals were present at more significant concentrations through ingestion than inhalation and dermal absorption for the pathways in this study. The values of HQ and HI declined in the following order: ingestion > dermal contact > inhalation. The six investigated metals had HQs and HIs lower than the safe level (=1) for children and adults, indicating that they had negligible adverse effects on health in Doha. The HI value decreased in the order of (As > Cr > Pb > Ni > Cu > Zn) for adults and children. It was found to be (As > Pb > Cr > Ni > Cu > Zn). Moreover, children's and adults' CRs were less than 1.0×10^{-6} for all metals except Cr, indicating a very low cancer risk. This is a preliminary study based on the available data of collected dust from roads in urban Doha. Thus, intensive research must be conducted to investigate the chemical behavior and sources of heavy metals in urban dust to enable comprehensive pollution control of PM emissions.

This study has several limitations related to the number of samples and sites, so more samples are recommended to be collected and characterized. Moreover, this study was conducted in the winter, but the seasonal impact on human health due to limited exposure to air pollution in the summer should be investigated.

Author Contributions: N.M. and D.A.-S. conducted the analysis and wrote the manuscript; H.A.-T. measured the metal concentration and provided the data; R.J.I. supervised the project and finalized the manuscript for submission. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data used in this work are all available within this manuscript.

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

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