The University of Tehran Press

Pollution

https://jpoll.ut.ac.ir/

Print ISSN: 2383-451X
Online ISSN: 2383-4501

Assessment of Human Health Risk of some Heavy Metals in Surface Dust of Selected Urban Areas in Pakistan

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Article Info

Article type:
Research Article

Article history:
Received: 8 July 2024
Revised: 25 September 2024
Accepted: 19 January 2025

Keywords:
Surface dust
Heavy metals
Nemerow Integrated Pollution Index
Human Health Risk
Pakistani Cities
Incremental Life time cancer risk

ABSTRACT

This study offers critical insights into the public health threats linked to urban dust exposure by systematically analyzing the pollution levels, sources, and associated health hazards of heavy metals including lead (Pb), cadmium (Cd), copper (Cu), nickel (Ni), and zinc (Zn). The Secondary data was collected on surface dust heavy metals from selected studies for last decade (2013-2023) in Charsadda, Karachi, Islamabad, Faisalabad, Lahore, Sargodha, and Murree. Health risk assessment was conducted to understand potential health risks for different urban communities. Nemerow Integrated Pollution Index (NIPI) was also estimated to distinguish heavy metals' pollution from artificial and natural sources. The results showed that heavy metal concentrations in cities had surpassed the limits of natural causes, and as a result, natural variables, particularly Cd, had little effect on heavy metal concentrations. Average cadmium levels were alarming and were found higher than the World Health Organization (WHO) guidelines in all cities except Sargodha (0.4 mg/kg). Additionally, average concentrations of Pb (4.96 to 636.39 mg/kg), Cu (11.4 to 200 mg/kg), Ni (14 to 181 mg/kg), and Zn (35 to 1190 mg/kg) significantly exceeded WHO guidelines. The estimated Hazard Index (HI) indicated a high chronic risk associated with exposure to contaminated dust. Carcinogenic risk assessment placed all age groups in a high-risk category, with adult males exhibiting the greatest vulnerability for all heavy metals i.e. Pb (5.86×10^{-}1), Ni (3.75×101), Cu (4.14×101), and Cd (1.31×101). There is need to expand the urban green spaces and strengthen regulations to mitigate heavy metal pollution in urban areas.

Cite this article: Nasim, I., Akram, T., Nawaz, R., Atif Irshad, M., Nasim, M., & Atiq ur Rahman, M. (2025). Assessment of Human Health Risk of some Heavy Metals in Surface Dust of Selected Urban Areas in Pakistan. *Pollution*, 11(2), 369-383. https://doi.org/10.22059/poll.2024.379123.2454

Publisher: The University of Tehran Press.
DOI: https://doi.org/10.22059/poll.2024.379123.2454

INTRODUCTION

Globally, surface dust (SD) pollution poses a major risk to human health and the environment in metropolitan areas. Human activities have a significant impact on densely populated cities due to industrial emissions, transportation, waste generation and urban development. These environmental problems are getting worse day by day in urban areas (Shah et al., 2020). As natural plant cover is being replaced by artificial constructed environments, the urban ecosystem's ability to self-monitor and regulate itself is compromised, which worsens the quality of the air in cities (Qadeer et al., 2020). Surface dust can include extremely high quantities of heavy metals (HMs) from both airborne and stationary sources, such as industrial activities, vehicular emissions, construction sites, transportation, smelting and chemical manufacturing, burning

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of household fuels, burning of garbage, urban development, and suspended particles from surrounding contaminated soils (Nawaz et al., 2023). According to Abdulaziz and Musayev (2017) and Jia et al. (2018), HMs pose a serious threat to human health as well as the ecosystem. Exposure to heavy metals has been associated with a gathering of health problems in humans, such as increased cancer risk, respiratory problems, neurological disorders, anemia, skin lesions, congenital abnormalities, and kidneys and liver dysfunction. Chronic exposure to heavy metals such as lead, cadmium, chromium, arsenic and nickel poses significant long term health risks (Sall et al. 2020). Although, these are found naturally in the Earth's crust, the majority of them enter into the environment through human activities including mining and metal smelting as well as industrial operations such as electroplating, leather tanning, metallurgy, electronics, and chemical industries. Moreover, HMs may be released into the environment via the burning of fossil fuels, vehicle exhaust, the manufacturing of cement, and the usage of compounds containing metals. Moreover, the geochemical cycles of HMs can be severely disrupted and could be released into the environment by the open dumping of hazardous waste and industrial effluents (Ali and Khan 2018; Rehman et al. 2021; Irshad et al., 2021; Alotaibi et al., 2023; Huqail et al., 2023).

Surface dust, which is present in indoors and outdoors, is the main source of human exposure to heavy metals (Sahakyan et al. 2016). Inhalation, ingestion, and skin contact are the three primary ways through which people can be exposed to metal contaminated surface dust (Mohmand et al. 2015). According to Shabbaj et al. (2018), oral ingestion—which happens accidentally with beverages, meals, and mucocilliary clearance—is thought to be the most dangerous mode of exposure. Studies have shown that anthropogenically polluted surface dust with heavy metals has negatively affected human health, either directly through inhalation or indirectly through the metals' entry into the food chain. Quantitative studies on the concentrations of heavy metals and their pollution levels in surface dust, particularly from contamination sources, have not been systematically gathered, despite the fact that several investigations on heavy metal pollution in surface dusts have been conducted recently (Yang, 2016). The health risk posed by the surface dust containing heavy metals is one of the environmental issues of Pakistan. The problem of road dust is rising due to the expansion of industry, infrastructure, and automobiles. Scientific information about heavy metals in road dust is sparse in Pakistani cities, particularly densely populated areas like Lahore and Faisalabad. The objectives of the present study are to determine the heavy metal concentrations in surface dusts, and to assess human health hazards of the surface dusts by health risk assessment model. Also, this study uses the Nemerow Integrated Pollution Index (NIPI) to assess the contamination level of heavy metals in surface dust of Pakistan's major cities. Furthermore, the risk of both cancer and non-cancerous diseases to humans resulting from inhaling surface dust (HMs) was also assessed in the present study.

MATERIAL AND METHODS

Pakistan occupies a strategic location in South Asia, bordering with China in the northeast, Afghanistan and Iran to the west, and India to the east-northwest direction (figure 1). Its geographical coordinates span from (23°35'-37°05') N, (60°50'-77°50') E. Extending from the Pamir Mountains in the north to the Arabian Sea in the south, Pakistan's diverse landscape also encompasses the majestic Hindu Kush range. According to the official census 2023 results, Pakistan's population stands at approximately 241.5 million people.

The study focused on seven cities of Pakistan including Lahore, Faisalabad, Sargodha, Karachi, Charsadda, Islamabad, and Murree. The time span for the present study range from 2013 to 2023. Secondary data was obtained from different reliable and authentic sources such as Google Scholar, Scopus, Google Advanced, Library Genesis, websites, books, and publications

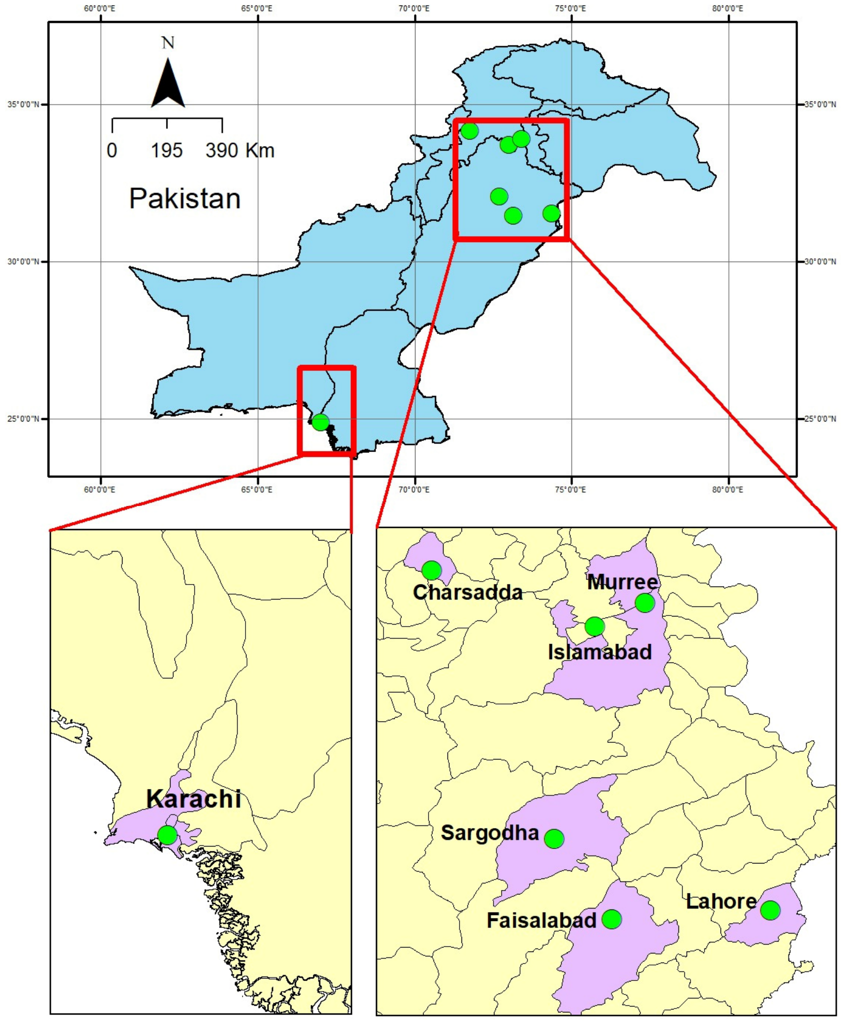

Fig. 1. Study area of different cities of Pakistan

of relevant organization (e.g. Environmental Protection Agency) on air quality, as shown in table 1. In the selected studies, dust samples were collected by plastic brushes. Brushes were cleaned with distilled water before taking the samples. Collected samples were stored in polythene bags for transportation. Samples were transferred to the polythene bags after removal of debris, if present. Selected heavy metals were analyzed by standards methods and instrumentation, as mentioned in table 1.

The levels of heavy metals found in surface dust, including zinc (Zn), copper (Cu), nickel (Ni), cadmium (Cd), and lead (Pb), were chosen and compared to WHO guidelines, as shown in Table 1. Over the designated time period, a thorough and meaningful evaluation of the heavy metals in surface dust and related health hazards in these places was made possible by the extensive data collection and rigorous comparison approach.

The Nemerow Integrated Pollution Index (NIPI) was employed to assess pollution levels and differentiate heavy metals originating from natural and anthropogenic sources. NIPI was estimated by using the following formulas (Yang et al. (2017);

$$PI_i = \frac{C_i}{S_i}$$ Equation I

$$\text{NIPI}= \sqrt{(IPI_{avg}^{2}+IPI_{\max}^{2})/2} \qquad \text{Equation II}$$

Where, Si is the reference background ratio, PIi is the elemental pollution ratio, IPIavg is the average value of PIi of the heavy metals, and IPImax is the highest value. Ci is the concentration of heavy metals in the surface dust (Table 1). Table 2 displays the NIPI grading standards.

This study examines the risks to human health that arise from inhaling heavy metals found in surface dust in Pakistan's urban areas. Although heavy metals can enter the body through various routes like skin contact, hand-to- mouth ingestion and inhalation, while inhalation is considered the primary pathway due to the characteristics of surface dust. There are three steps in the assessment process:

1. Estimate the average daily intake (ADD) of heavy metals by the exposed population through inhalation using established methodologies
2. The Hazard Quotient (HQ) is a tool used to assess each heavy metal's possible non-carcinogenic health effects.
3. Incremental Lifetime Cancer Risk (ILCR) assesses the likelihood of developing cancer from chronic exposure to these heavy metals

This study incorporates a well-established methodology from the US Environmental Protection Agency's Risk Assessment Guidance for Superfund (USEPA, 1989) to estimate the average daily dose (ADD) in mg/kg of heavy metals inhaled from surface dust as shown in table 3. ADD was estimated using the equation (III);

$$ADD = \frac{C \times IR \times EF \times ED}{BW \times AT} \qquad \text{Equation III}$$

- ADD stands for the Average Daily Dose of Pollutants.

Table 1. Surface dust heavy metals in different cities of Pakistan from literature

Sr. #	**Cities**	**Pb (mg/kg)**	**Cd (mg/kg)**	**Zn (mg/kg)**	**Ni (mg/kg)**	**Cu (mg/kg)**	**Analyzer/ Instrumentation**	**References**
1	Charsadda	215.01	4.96	636.39	144.77	81.14	AAS	Jan et al. (2021)
2	Karachi	566	3.5	1190	181	200	WD-XRF Analyzer	Ahmed et al. (2019)
3	Islamabad	104	5	116	23	52	FAAS	Faiz et al. (2019)
4	Faisalabad	65	3.5	95	14	45	AAS	Qadeer et al. (2020)
5	Lahore	78	3.5	104.5	15.5	43	AAS	Qadeer et al. (2020)
6	Sargodha	61.8	0.4	137	5	11.8	ICP-MS	Mohmand et al. (2015)
7	Murree	145.8	8.4	890	47.8	156.9	FAAS	Abbasi et al. (2013)
WHO		100	3	300	50	100		Jan et al. (2021)

Table 2. Grading standards of Indices of Nemerow Integrated Pollution Index (NIPI)

Sr. No	Grades of Pollution Risk	P	Source
1	Safety	$P \leq 0.7$	Natural
2	Warning Line	$0.7 < P \leq 1$	Natural/Artificial
3	Slight Pollution	$1 < P \leq 2$	Artificial
4	Moderate Pollution	$2 < P \leq 3$	Artificial

- C represents the Concentration of heavy metals in surface dust.
- IR is the Inhalation Rate
- EF stands for Exposure Frequency.
- ED represents Exposure Duration.
- BW is the Body Weight.
- AT stands for Average Exposure Time (USEPA, 1989)

The non-carcinogenic risk associated with specific heavy metal contaminants in surface dust was assessed using the Hazard Quotient (HQ). The methodology outlined in Equation (IV), as recommended by the USEPA in 1989, was utilized in the present analysis to determine the average daily exposure levels for each category of individuals. Moreover, the hazards associated with various heavy metal components were evaluated using Equation (V) to compute the Hazard Index (HI).

$$HQi = \frac{ADDi}{RfDi} \qquad \text{Equation IV}$$

$$HI = \sum HQI = \sum \frac{ADDi}{RfDi} \qquad \text{Equation V}$$

The quantity of a certain pollutant that can be consumed during respiration is denoted by the term "reference dose (RfD)" in Equation (III). It assists in determining if prolonged exposure to that contaminant in the environment has any detrimental health consequences (USEPA, 1989). Present study evaluated each element's total non-carcinogenic risk using the hazard index (HI). HI of less than or equal to one indicates that there is little to no combined non-carcinogenic health risk from all of the contributing factors. On the other hand, HI higher than 1 denotes a health risk that is non carcinogenic (USEPA, 2004). Furthermore, when a pollutant's hazard quotient is less than 1, it indicates that there is little chance of non-carcinogenic health effects from that particular pollutant. Conversely, if HQi is higher than 1, it implies that the pollutant has a non-carcinogenic risk attached to it.

The average daily dose of each group of exposed individuals was determined, and the carcinogenicity of specific cancerous pollutant (heavy metals) in surface dust was evaluated using the ILCR risk technique (Attiq et al., 2024).

$$ILCR = ADD \times SF \qquad \text{Equation VI}$$

The slope factor, or SF, is the highest likelihood that the human body will be exposed to a particular dosage of a particular pollutant and develop cancer (USEPA, 1989). Table 4 presents the detailed data pertaining to the RfD and SF of the heavy metals. Humans can get cancer

Table 3. The value of exposure factors for Average Daily Dose

Exposure factors	Physical meaning	Unit	Male Adults	Female Adults	Children
IR	Inhalation rate	mg/m^3	16.6	13.5	8.6
EF	Exposure frequency	Days/years	365	365	365
ED	Exposure duration	years	30	30	6
BW	Body weight	kg	67.3	57.3	15
AT-non-carcinogenic	Average non-carcinogenic	days	365×72.4	365×72.4	365×18
AT-carcinogenic	Average-carcinogenic risk exposure time	days	365×ED	366×ED	367×ED

(Source: USEPA, 1989)

as a result of prolonged exposure to a specific carcinogen. Consequently, ILCR is utilized to assess the possibility of cancer in the human body. According to USEPA (2009), those who are exposed to a pollutant with ILCR of 10^{-6} to 10^{-4} may be at risk of developing cancer. This is because there is a higher chance that one cancer case will arise for every 10,000 to 1 million people. As a result, the studies divided the carcinogenic risk into three categories, which are as follows:

- Low risk (− ∞ to 10-6): Considered acceptable
- Medium risk (10-6 to 10-4): Indicates possible carcinogenic risk;
- High risk (10-4 to + ∞): Requiring prompt and careful observation (USEPA, 2009).

RESULTS & DISCUSSION

The concentrations of heavy metals, including lead (Pb), cadmium (Cd), zinc (Zn), nickel (Ni), and copper (Cu), pose a significant threat to urban ecosystems. These metals are released into the environment from mining, battery manufacturing, automobile production, and refineries. Lead levels in surface dust varied considerably among cities, ranging from 4.96 mg/kg to 636.39 mg/kg, as shown in Figure 2. This variation highlights a critical public health concern, with residents in certain cities, such as Charsadda, Karachi, and Murree, experiencing lead exposure levels that exceed World Health Organization (WHO) guidelines. The awareness of lead (Pb) in surface dust has been observed to exceed permissible limits in various places. Filonchyk (2021) explained that high surface dust concentrations of Pb during an excessive dust storm in East Asia, at the same time as Tooms (2023) observed that irrelevant upkeep practices can lead to great Pb contamination in the dust. Darma (2022) highlighted the effect of gold ore mining on Pb concentration in mining and residential areas with the exceeding threshold level. Al-Omran (2022) also noted the presence of Pb in indoor dust, despite the fact that the ranges have been observed in above the permissible limit. Similarly, cadmium levels were alarming, with nearly all cities surpassing the WHO guidelines, except Sargodha (0.4 mg/kg). The attention of Cd in surface dust exceeds permissible limits in various locations, posing ability of health impacts. In Gazipur, Bangladesh, Cd ranges had been 82.7 times better than the endorsed limits (Kabir, 2021). Similarly, in Detroit, Michigan, Cd concentrations had been multiplied, with 80% of samples exceeding limits (Denny, 2022). In a metal industry town in China, Cd ranges were additionally excessive, mainly within the metal commercial district and areas with heavy visitors (Zhu, 2021). These findings highlight the substantial trouble of Cd contamination in surface dust, necessitating urgent action to mitigate health impacts. Zinc concentrations in surface dust ranged from 35 mg/kg to 1190 mg/kg, with Charsadda, Karachi, and Murree recording levels above the WHO guidelines. The attention of Zn in surface dust has been observed to exceed permissible limits in numerous studies. In Japan, Andarani (2021) observed that the once a year mean concentration of Zn in the Umeda River passed the environmental standards. Similarly, Chen (2022) reported that the mean concentration of Zn in surface dust in Wuhan, China became higher than the soil which indicates a contamination. In Vietnam, Dat (2021) found that Zn became the maximum concentrated heavy metals in surface dust, contributing to potential ecological risk. In Bangladesh, Rahman (2021) also found higher Zn concentrations

Table 4. Reference dose and slope factors parameters of heavy metals

Elements	RfD	SF	Carcinogenic/non-carcinogenic
Pb	3.52E-03	0.0003	Carcinogenic
Cd	1.00E-03	6.30E+00	Carcinogenic
Zn	3.01E-04	1.51E+01	Carcinogenic
Ni	2,06E-02	8.40E-01	Carcinogenic

(Source: USEPA, 2009)

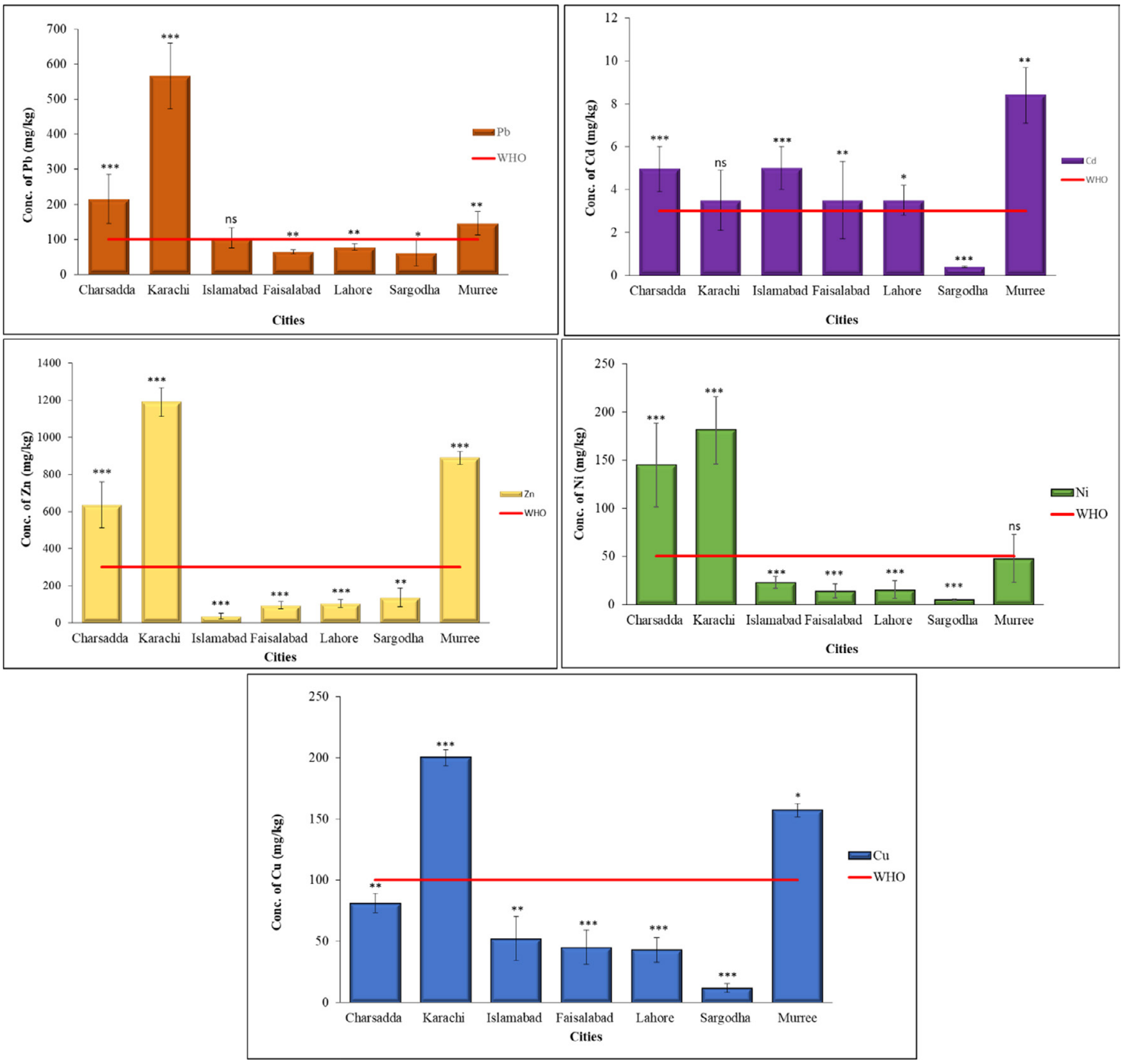

Fig. 2. Concentrations of heavy metals in surface dust of urban areas as compared to WHO acceptable limits.
ns = non-significant
** = Significant p-value <0.005*
*** = More significant p-value <0.01*
**** = Highly significant p-value<0.001*

in indoor dust samples, even though the health risks have been deemed to be within safe limits. These studies collectively suggest that Zn contamination in surface dust is a vast trouble, with capability of ecological and human health implications. Nickel concentrations, though less variable (14 mg/kg to 181 mg/kg), showed significant inter-city differences, with Charsadda and Karachi exceeding WHO guidelines. The concentration of Ni in surface dust has been observed to exceed permissible limits in a few regions, mainly during extreme dust storms (Filonchyk, 2021). However, lengthy-time period monitoring in city environments has proven a sluggish reduction in Ni tiers, with values constantly below the global threshold limit (Kim, 2014). The capability effect of the long-range transport of Asian dust debris on Ni stages has additionally been referred to Kim (2014). These findings highlight the need for persevered tracking and shielding measures to mitigate the health and environmental risks associated with high Ni concentrations in surface dust. Copper levels ranged from 11.4 mg/kg to 200 mg/kg, with only Karachi and Murree surpassing WHO guidelines. The concentration of Cu in surface dust has been found to exceed permissible limits in various studies. Zhu (2021) identified excessive Cu levels in street dust in a steel industry metropolis can cause the risks for kids. Similarly, Zhao (2021) found high Cu levels in indoor dust from college libraries, indicating capacity ecological risks. These findings advocate a huge issue of Cu contamination in surface dust, warranting similarly investigation and action to mitigate potential fitness and environmental dangers.

Analysis of the results revealed that there was a significant range in the level of overall contamination across the several HMs. Results from PI (Table 5) and NIPI (Table 6 and Fig. 3) show that cadmium was above the moderately polluted (< 3) among the all the HMs. While, other metals were above the warning line limit (<1).

Based on Equation (III), Figure 4 displays the ADD (mg/kg) of three different visible groups in seven urban areas. The hazard quotient to pollutants for adult male, female, and children was shown in each column. Each of these seven cities is represented by the appropriate shade on the scale. The prevalence of HQ varies significantly between cities and exposed populations, as seen in Figure 4. Notably, across all age groups, the average HQ for surface dust HMs such Pb, Cd, Zn, Ni, and Cu shows the highest values. A range of studies have assessed the health risk related to heavy metals in surface dust. Mainka (2021) discovered that at the same time as heavy metals did not exceed appropriate limits, the cumulative health risks had been high. Zgłobicki (2021) mentioned that regardless of high concentrations of Zn, Cd, and Cu in surface dust, the threat of non-carcinogenic consequences turned into low, although cancer risk for children became a problem. Zhao (2021) further discovered that at the same time as Cd and As posed a carcinogenic risk in indoor dust. Kabir (2022) additionally mentioned excessive stages of Zn in roadside dust showed that no non-carcinogenic risk or tolerable levels of carcinogenic risks for certain metals. These studies together propose that heavy metals may additionally exceed permissible limits and health impacts from surface dust are normally desirable.

Findings of the present study showed considerably greater HQ of surface dust lead (Pb), cadmium (Cd), zinc (Zn), nickel (Ni), and copper (Cu) in all age categories. It provided significant data on the varying exposure patterns and hazards that various demographic groups encounter. It is also notable to observe that adult males regularly have significantly higher HQ levels of surface dust heavy metals than do females and children. This highlights the critical necessity for

Table 5. Pollution Index of Heavy Metals in selected cities of Pakistan

Cities	**Cu**		**Ni**		**Pb**		**Zn**		**Cd**	
	C$_i$ (mg/kg)	**PI**	**C$_i$** (mg/kg)	**PI**	**C$_i$** (mg/kg)	**PI**	**C$_i$** (mg/kg)	**PI**	**C$_i$** (mg/kg)	**PI**
Charsadda	81.14	0.8	144.77	2.9	215.01	2.2	636.39	2.1	4.96	1.7
Karachi	200	2.0	181	3.6	566	5.7	1190	4.0	3.5	1.2
Islamabad	52	0.5	23	0.5	104	1.0	35	0.1	5	1.7
Faisalabad	45	0.5	14	0.3	65	0.7	95	0.3	3.5	1.2
Lahore	43	0.4	15.5	0.3	78	0.8	104.5	0.3	3.5	1.2
Sargodha	11.8	0.1	5	0.1	61.8	0.6	137	0.5	0.4	0.1
Murree	156.9	1.6	47.8	1.0	145.8	1.5	890	3.0	8.4	2.8

C$_i$ was divided by S$_i$ (100 for Cu, 50 for Ni, 100 for Pb, 300 for Zn, 3 for Cd)

Table 6. Estimation of Nemerow Integrated Pollution Index (NIPI) for different Heavy Metals

Heavy Metals	**Average PI**	**Maximum PI**	**NIPI** **NIPI=** $\sqrt{(IPI_{avg}^2 + IPI_{\max}^2)/2}$
Cu	0.8	2.0	1.5
Ni	1.2	3.6	2.7
Pb	1.8	5.7	2.2
Zn	1.5	4.0	3
Cd	1.4	2.8	4.2

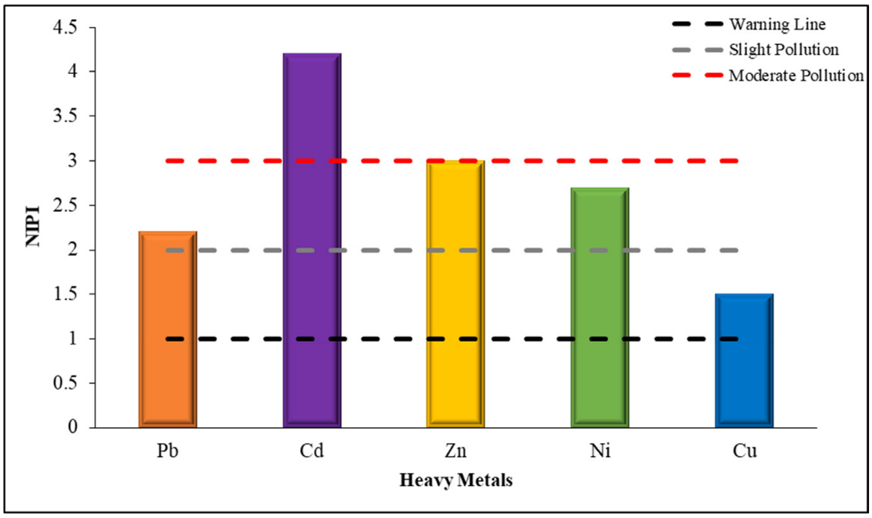

Fig. 3. Nemerow integrated pollution index of selected heavy metals

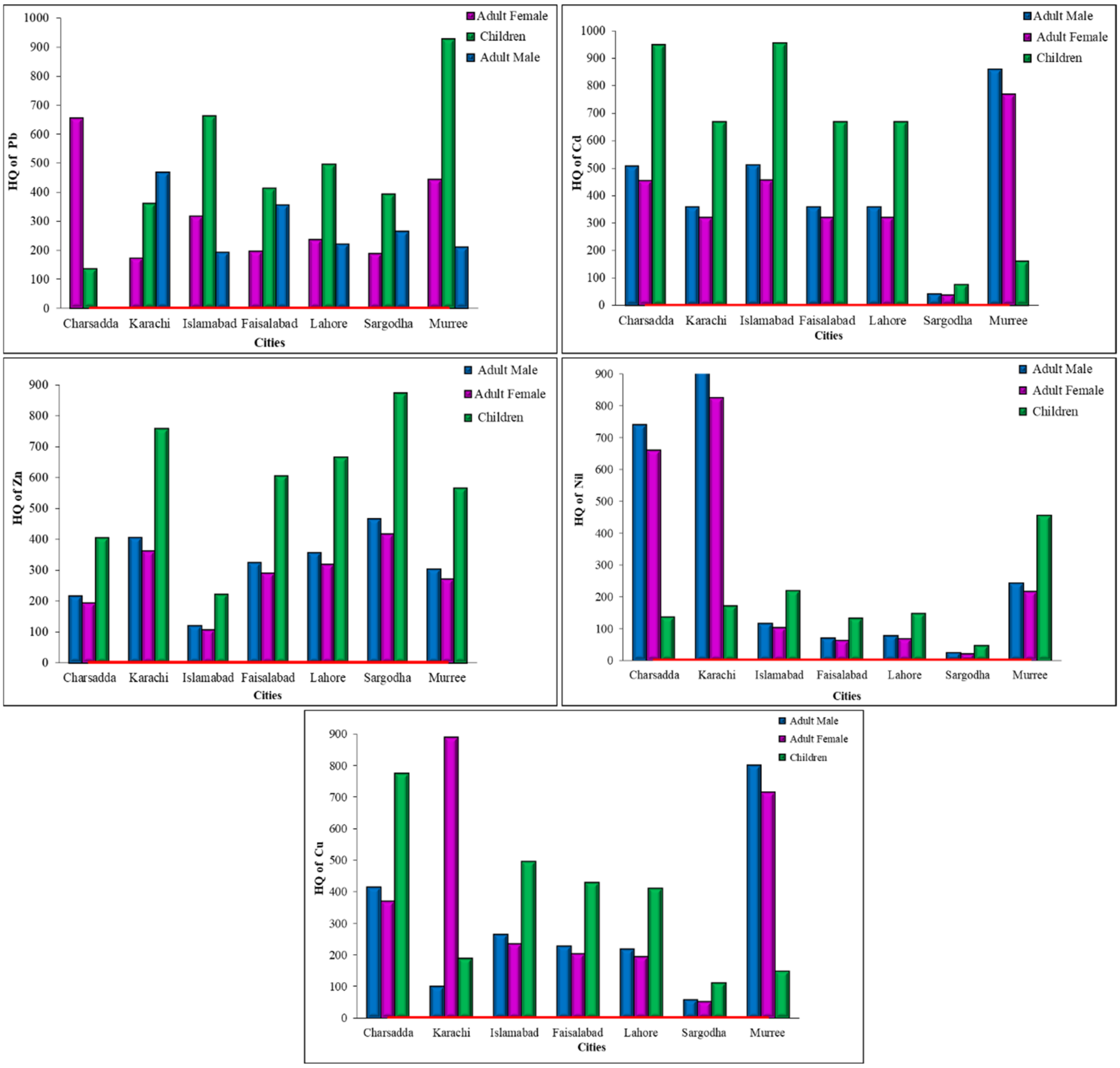

Fig. 4. Assessing the Hazard Quotient to Heavy Metals from Surface Dust in Selected Urban Areas

focused actions to safeguard our society's most vulnerable people. All age groups had higher HQ values for surface dust heavy metals, indicating how widespread heavy metal pollution is in the selected cities' air. The public's health is significantly affected by this prolonged exposure; as heavy metals are known to have a number of harmful impacts on health.

Furthermore, for each of the three exposed groups, the ILCR values associated with additional heavy metals are consistently within the unacceptable range, indicating a higher risk threshold that may have carcinogenic consequences. The findings showed the following relative effects of distinct heavy metal pollution on the non-carcinogenic risk index: With a contribution of 29.0%, Cd is the largest contributor, followed by Ni (22.6%), Zn (19.3%), Cu (15.1%), and Pb (14.8%), as shown in figure 5. These results showed that exposure to Cd in surface dust of Pakistan's chosen cities, with the exception of Sargodha, had a significant carcinogenic risk to all three categories. These exclusions serve to emphasize how serious the situation is in urban area and how urgent it is to address the hazards involved. Figure 6 displays in detail each exposed group's Non-Carcinogenic Hazard Index (HI) in the selected cities. The HI for adult male's ranges from 1.95 in Lahore to 0.63 in Sargodha. While the HI of female adults varies from 0.51 in Sargodha to 1.97 in Lahore, that of children ranges from 0.91 in Islamabad to 2.23 in Faisalabad. The results highlight the significant influence of heavy metals found in surface dust; children had the greatest average comprehensive non-carcinogenic risk (2.23), followed by females (1.97) and male adults (1.95). Moreover, it is apparent that children in Lahore, Faisalabad, Karachi, and Sargodha appear to be at a complete non-carcinogenic risk from breathing in heavy metals from surface dust. A range of studies have found regarding ranges of Cd in surface dust, with a few exceeding permissible limits. Zgłobicki (2021) observed that even as Cd levels in road dust have been accelerated and did not pose a non-carcinogenic threat. However, Zhao (2021) and Gupta (2022) each suggested that Cd concentrations in indoor and outdoor dust,

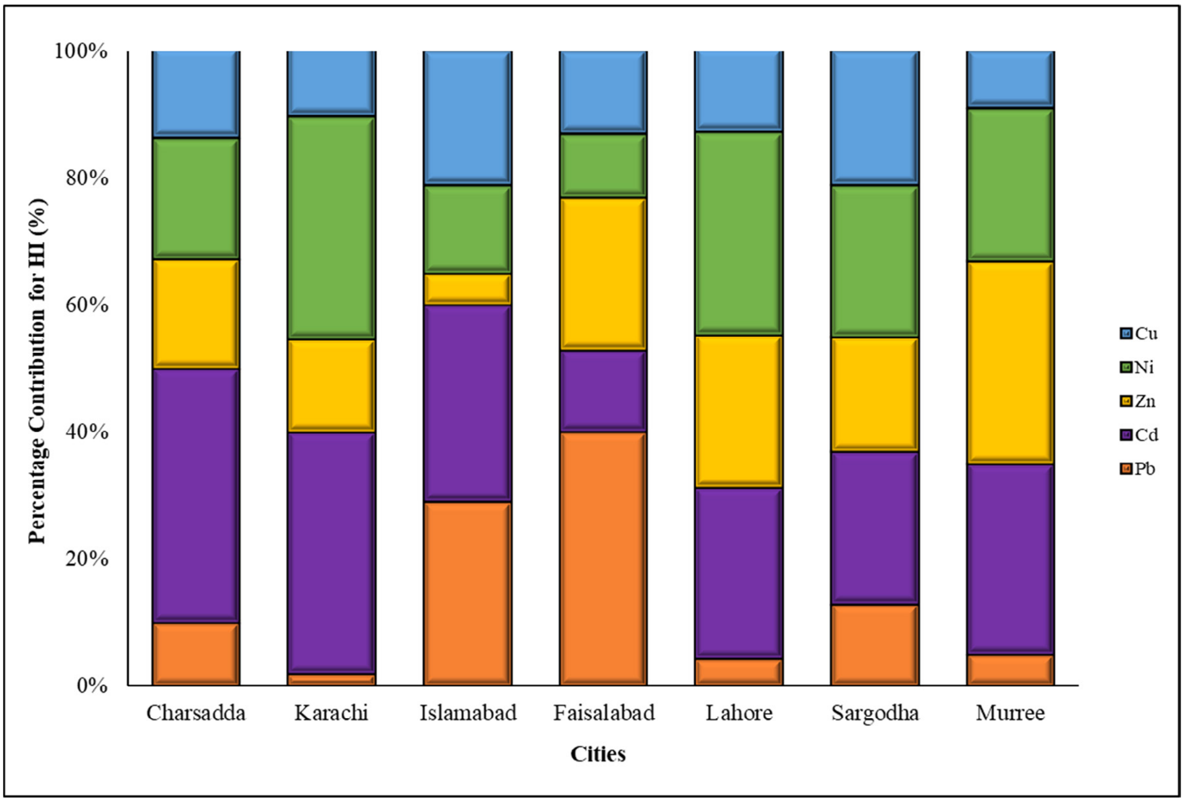

Fig. 5. Hazard Index (HI) percentage contribution in urban areas to show the main heavy metal contributor

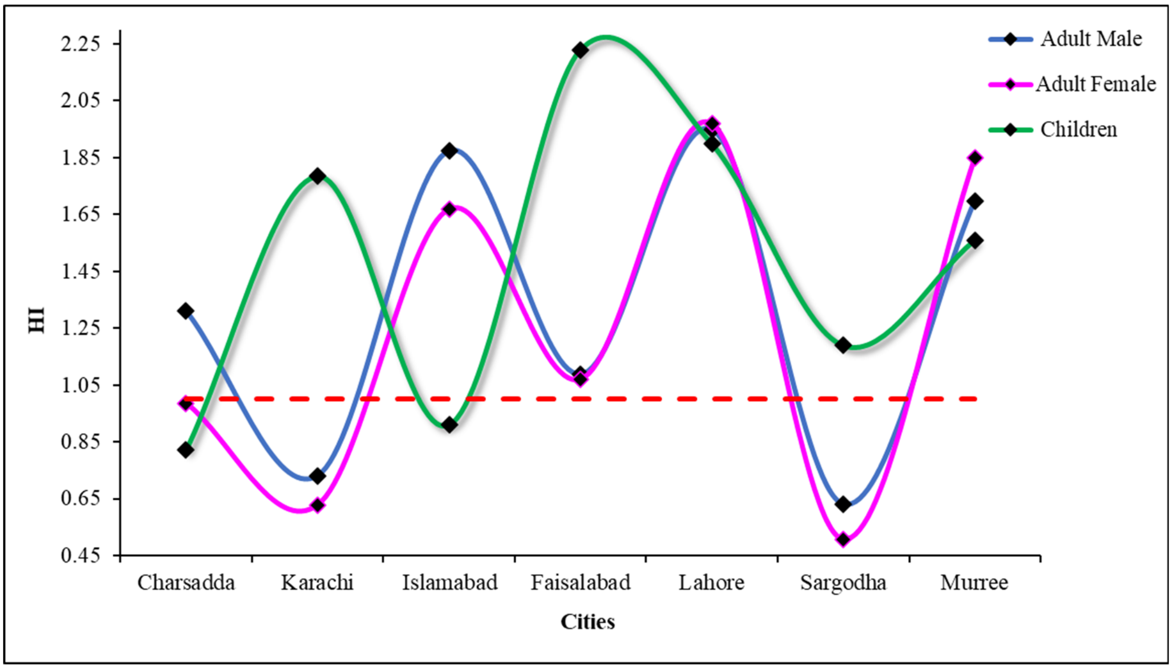

Fig. 6. Assessment of Hazard Index (HI) of Heavy Metals in Surface Dust for Exposed Groups in Urban Areas

respectively, surpassed permissible limits, posing a potential carcinogenic chance. Kabir (2021) also discovered high Cd levels in surface dust however concluded that the related health impacts have been insignificant. These findings endorse a need for in addition studies and movement to cope with Cd contamination in surface dust. A variety of studies have found concerning stages of copper (Cu) in surface dust, with some exceeding permissible limits. Zgłobicki (2021) discovered that even as Cu degrees in surface dust had been increased, they did not longer pose a non-carcinogenic risk. However, Kabir (2021) and Gupta (2022) each stated that Cu stages in surface dust surpassed permissible limits. Zhao (2021) also observed that copper (Cu) levels in indoor dust were higher than soil background values but did not present a significant non-carcinogenic risk. However, these findings suggest that while Cu levels in surface dust may not pose a considerable non-carcinogenic threat, they do exceed permissible limits and may pose an ecological hazard.

The International Agency for Research on Cancer's (IARC) 2021 classification of chemicals with confirmed carcinogenicity states that the concentrations of Pb, Cd, Ni, and Cu were shown to have carcinogenic properties. Equation (IV) was used to determine the Incremental Lifetime Carcinogenic Risk (ILCR) values that are given in figure 7. Notably, the figure's high-risk level is shown by a red line. According to the investigation, adult males experience greater ILCR values than adult females, while children show higher ILCR levels than female. For surface dust heavy metals, the typical ILCR values for males are Pb (5.86×10^{-1}), Ni (3.75×10^{1}), Cu (4.14×10^{1}), and Cd (1.31×10^{1}). Pb (1.36×10^{0}), Cd (1.01×10^{0}), Cu (3.21×10^{1}), and Ni ($2.91\times10^{\circ}$) are the rankings for children. The current rankings for adult female Pb (5.59×10^{-1}), Ni (1.39×101), Cd (2.85×100), and Cu (3.21×101) are as follows. It is noteworthy that adult males had an average ILCR (Incremental Lifetime Cancer Risk) score of 6.50×10^{0} for surface dust cadmium (Cd), which is a very high level of risk. Furthermore, for each of the three exposed groups, the ILCR values associated with additional HMs are consistently within the unacceptable range, indicating a higher risk threshold that may have carcinogenic consequences. With the exception of Sargodha, these findings demonstrate that all three categories face a significant carcinogenic risk from exposure to Cd surface dust in Pakistan's chosen cities. These exclusions serve to

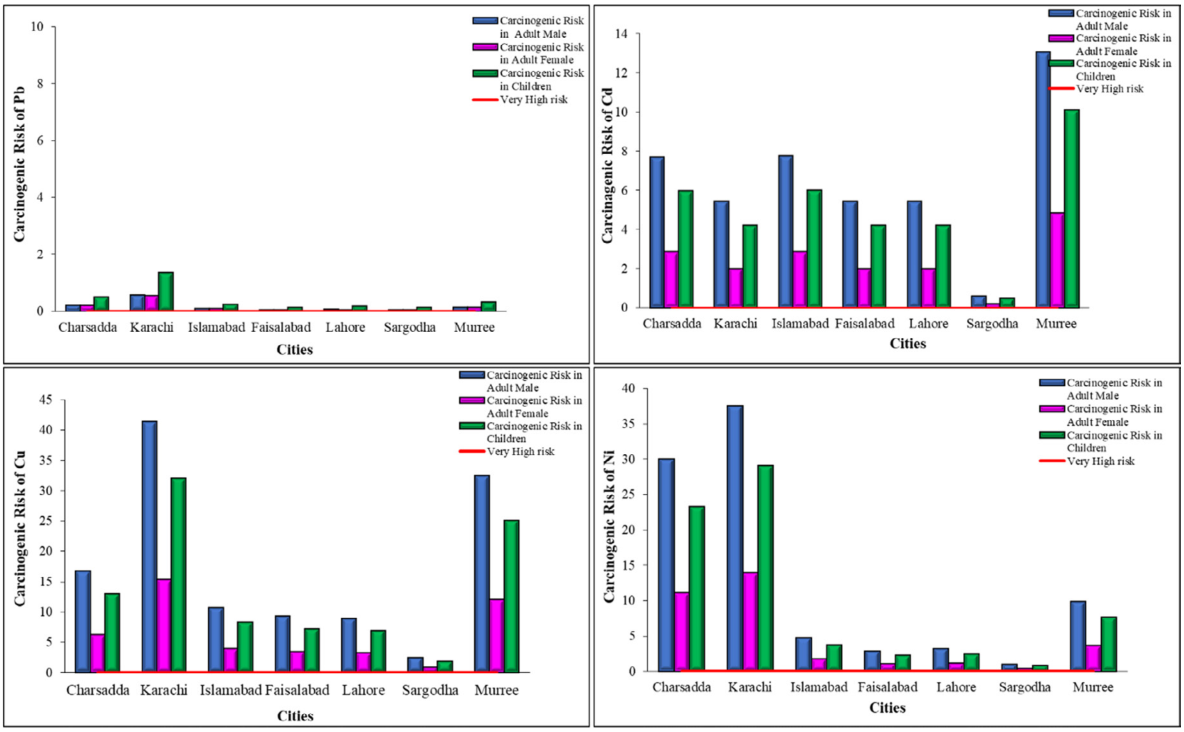

Fig. 7. Assessment of the incremental lifetime cancer risk due to heavy metals in surface dust for various age groups in urban areas

emphasize the seriousness of the situation in some areas and the urgency of addressing the risks. A collection of research has discovered on contamination of nickel (Ni) in surface dust, with some indicating that those levels exceed permissible limits. Zhao (2021) and Zgłobicki (2021) both discovered that the carcinogenic threat of Ni in indoor and road dust, respectively, become generally applicable, however Kabir (2021) and Gupta (2022) mentioned that the concentration of Ni in the surface dust exceeded permissible limits, posing an ability to cause cancers. A variety of research from 2021 to 2022 have highlighted the regarding contamination of lead (Pb) in surface dust, with Abdulaziz (2022) and Mainka (2021) explained that Pb concentrations in surface dust exceeded permissible limits. Abdulaziz (2022) additionally determined that the cumulative incremental lifetime cancer risk values for Pb in ambient $PM_{2.5}$ and PM_{10} indicated a likely chance of most cancers from inhalation of those contaminants. Similarly, Jeong (2022) recognized that the carcinogenic risk of Pb in surface dust exceeded the most threshold level, mainly in children. These findings underscore the urgent need for techniques to govern Pb pollutants and decrease the associated health dangers.

CONCLUSION

This study has uncovered a concerning situation of surface dust pollution in the cities under investigation by meta-analysis. The findings reveal that heavy metal concentrations in Pakistani cities have significantly exceeded, particularly Cd which has minimal influence. Alarmingly, the average cadmium levels in nearly all cities surpassed the WHO guidelines, except for Sargodha (0.4 mg/kg). Lead (Pb) concentrations ranged from 4.96 mg/kg to 636.39 mg/kg, copper (Cu) from 11.4 mg/kg to 200 mg/kg, nickel (Ni) from 14 mg/kg to 181 mg/kg, and zinc (Zn) from 35 mg/kg to 1190 mg/kg, all substantially surpassing permissible limits. The calculated Hazard Index (HI) suggests a high chronic risk from exposure, and the carcinogenic risk assessment places all age groups in the high-risk category, with adult males showing the greatest vulnerability, with Pb at 5.86×10^{-1}, Ni at 3.75×10^{1}, Cu at 4.14×10^{1}, and Cd at 1.31×10^{1}. It is recommended to practice efficient methods to lessen the pollution caused by heavy metals in metropolitan areas. These methods include locating and removing pollution sources, encouraging environmentally friendly industrial techniques, and educating the public about the health concerns associated with these practices. Coordinated actions are necessary to minimize long-term exposure dangers and safeguard public health.

ACKNOWLEDGMENTS

The authors extend their appreciation to the Department of Environmental Sciences, The University of Lahore.

GRANT SUPPORT DETAILS

The present research did not receive any financial support.

CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy have been completely observed in the meta-analysis.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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