American Journal of Environment and Climate (AJEC)

ISSN: 2832-403X (ONLINE)

VOLUME 5 ISSUE 3 (2026)



PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Environment and Climate (AJEC)

Volume 5 Issue 3, Year 2026
ISSN: 2832-403X (Online)
DOI: https://doi.org/10.54536/ajec.v5i3.7879
https://journals.e-palli.com/home/index.php/ajec

Descriptive Statistics of Selected Heavy Metal in Dust Particles from Three Sampling Sites Within Ibadan Metropolis, Southwestern Nigeria

Apanpa Kazeem Abidemi[1*], Oladimeji Razaq Gboyega[2], Adeogbo Ayoade Olusola[1]

Article Information

Received: March 15, 2026
Accepted: May 30, 2026
Published: November 14, 2026

Keywords

Ibadan Metropolis, Mechanic Workshops, Motor Parks, Roundabouts / Highways, Street Dusts

ABSTRACT

This study investigates the concentration and distribution of heavy metals in dust particles from three sampling sites within Ibadan Metropolis. A total of 20 dust samples were collected from three distinct areas: Mechanic workshops (MWK), Motor parks (MPK), and Roundabouts/highways (RHW). The samples were prepared and processed at the geochemistry laboratory of the Polytechnic Ibadan. The process samples were analysed using Induced Couple Plasma- Atomic Emission Spectrometry (ICP-AES) at PAM BEE Analytical Laboratory Ibadan. The heavy metals analyzed include Cr, Zn, Fe, Pb, Cu, and Ni. The results indicated a wide range of heavy metal concentrations across the sampled locations. Cr ranged from 8.67 - 60.52mg/kg with a mean of 23.56 mg/kg, Zn from 64.15 - 534.22 mg/kg with a mean of 244.28 mg/kg, Fe from 319.62 - 3945.51 mg/kg with a mean of 3766.6 mg/kg, Pb from 13.715 - 368.19 mg/kg with a mean of 67.13 mg/kg, Cu from 13.72 - 61. Mg/kg with a mean of 30.79 mg/kg, and Ni fro20.81-33.18 mg/kg with a mean of 19.03 mg/kg. The results demonstrated that Pb was the dominant contaminant, reaching levels of considerable contamination (CF ≈ 3.35; Igeo ≈ 1.3), followed by moderate enrichment of Zn and Cr. Ni, Cu, and Fe remained within the low contamination range, suggesting primarily natural inputs with minimal anthropogenic influence. The overall PLI value (<1) indicates that, on average, the study area is not heavily polluted. However, localized hotspots, particularly around mechanic workshops and motor parks, present elevated risks. The contamination pattern followed the order: Pb > Zn > Cr > Ni > Cu > Fe, with Pb clearly emerging as the most concerning pollutant due to its toxicity and persistence. The findings underscore the need for continuous monitoring of heavy metals in urban dust, particularly Pb, which remains a significant environmental hazard. Although the overall pollution load index suggests acceptable site quality, the considerable contamination of Pb points to localized anthropogenic sources that should be addressed through stricter environmental management and control measures.

INTRODUCTION

Heavy metal pollution in street dust remains a pressing environmental and public health issue that necessitates ongoing research and intervention strategies. Ibadan the capital of Oyo state, according to recent data, has a population of approximately 3.6 million people within the metropolitan area, making it the third most populated city in Nigeria after Lagos and Kano and is known for significant traffic congestion due to its large population and inadequate road infrastructure, it often experiences heavy traffic during the peak hours. The congestion currently being experience is as a result of rapid urbanization, lack of efficient public transportation and poor urban planning. At 3,080 square kilometers, it is the country's largest city by geographical area (Adelekan, 2016). This work study the concentration of heavy metals in the district areas of Ibadan metropolis, elucidate the possible source and possible health risk of each of the elements.

Location & Geology of the study area: Ibadan the study area is situated in the southwestern part of Nigeria. (Figure 1) It lies between latitude 70 19' to 7o 15' and longitude 3o 53' to 30 58'. It is located near the grassland boundary of southwestern Nigeria. Thus, it lies in a transition zone between the humid and sub humid tropical climates. The climates are tropical with well-defined rainy and dry seasons [United Nation World Urbanization Prospects (UNWUP)]. Over the past few decades, the city has undergone significant urbanization and industrialization leading to increases in vehicular traffic, industrial emissions and construction activities. These factors contribute to the accumulation of heavy metals in the urban environment. The area covered is about 200 km2 and all the locations visited were linked by major roads (Figure 1).

Ibadan is underlain predominantly by the Precambrian Basement Complex Rocks, which are some of the oldest rocks in Nigeria. These rocks include Migmatite-gneiss complex which dominate the area, consisting of banded gneiss, Migmatites, and minor granites. Other rocks are quartz –schist and quartzites which occur as ridges, as well as granites and pegmatites which are found as intrusive bodies (Fig. 2). These are rocks intruded by pegmatite, quartz veins, aplites and dolerite dykes. Over 75% of the rocks in Ibadan are banded gneisses while granite, gneisses and quartzite share the remaining composition respectively, (Dada, 2006). However, the ridges in Ibadan mainly composed of quartzite are relatively more resistant to erosion than the deeply weathered gneisses, granites amphibolite and dolerites, Olayinka *et al.*, 1999).

[1] Department of Geology, The Polytechnic, Ibadan, OyoState Nigeria
[2] Department of Geological Sciences, Osun State University, Nigeria
[*] Corresponding author's e-mail: apanpacousym@gmail.com

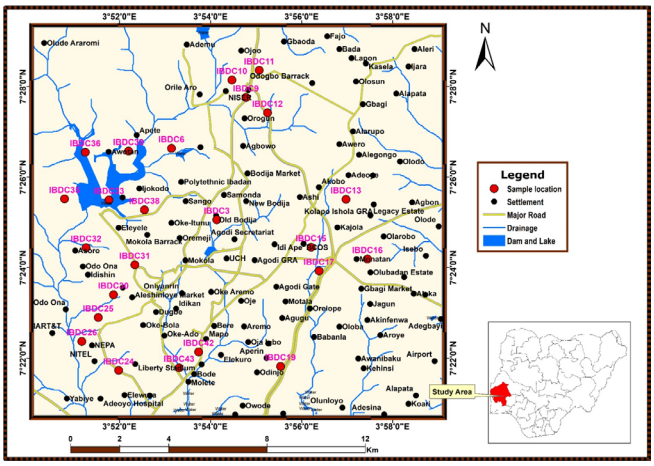


Figure 1: Location Map of the selected Study Areas in Ibadan Metropolis

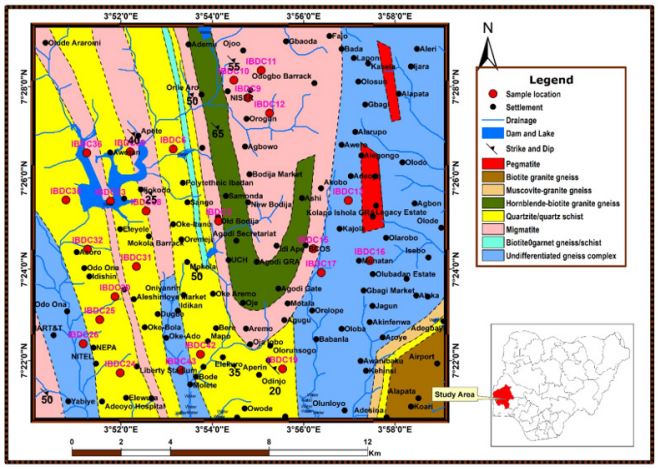


Figure 2: Geologic Map of Ibadan

LITERATURE REVIEW

In recent years much attention has been paid to heavy metal contamination with street dust particles in many parts of the world. (Gope, *et al.*, 2017, Al Khashman, 2004 and Ashrafi *et al.*, 2014) analyzed Street dusts to be composed of mineral and organic particles of varying origin, including industrial sources and those related to vehicle traffic. Street dust is a significant reservoir for heavy metals, which can originate from various anthropogenic activities such as industrial processes, vehicular emissions, and construction activities. Natural and anthropogenic heavy metals comprise the most important part of the dusts' in organic components (Basart, *et al.*, 2016 and Burgos *et al.*, 2008). The main components of the dust are quartz and feldspar, but it also contains heavy metals such as Cd, Cu, Pb and Zn.

The sources of heavy metals in street dust can be complex and multifactorial. Tang *et al.* (2017) explored the contamination levels in a coal-mining city in China and identified mining activities and traffic emissions as primary contributors to heavy metal accumulation in street dust. This study highlighted the need for targeted pollution management strategies in cities with specific industrial profiles. In contrast, a study by Khademi *et al.* (2019) focused on the environmental impact of industrial activities on heavy metal distribution in street dust and soil. Their findings indicated that industrial emissions significantly influenced the concentration of heavy metals in urban environments, suggesting that regulatory measures are necessary to mitigate emissions (Khademi *et al.*, 2019). Moreover, it has been suggests that plastic pollution may also serve as a vector for heavy metals, complicating the issue of urban dust pollution (Abbasi *et al.*, 2017).

The health implications of heavy metal exposure through street dust are profound. Studies have demonstrated that prolonged exposure to heavy metals, such as lead and cadmium, can adversely affect human health, including immune system dysfunction and increased cancer risks (Ebrahimi *et al.*, 2020). This is particularly concerning in urban areas, where populations may be more vulnerable due to higher exposure rates. Disproportionate accumulation of heavy metals is a serious threat to living organisms; they pollute the natural environment and enact toxic impact on living humans. (Hemati & Rahimi, 2020). Some heavy metals are essential to life; however, it must be taken into consideration that at higher levels, they can also impose some toxicological risk (Christoforisdis & Stamatis, 2009; Hemati & Rahimi, 2020). Similarly, studies has also indicated that urban street dust contained elevated levels of heavy metals such as lead and cadmium, raising concerns about the potential health impacts on

residents (Keshavarzi *et al.*, 2015). The chemical speciation of these metals provided insight into their bioavailability and toxicity, further emphasizing the importance of risk assessment strategies in urban settings. This underscored the necessity of assessing human health risks associated with heavy metal exposure from street dust, particularly in densely populated megacities (Rahman *et al.*, 2019).

The geochemistry of street dust provides a wealth of information about the state of the urban environment. At the same time, street dust can be a health hazard due to its re-suspension. It becomes a component of ground level atmosphere, in the living zone of humans, plants and animals. Therefore, it can penetrate human organisms relatively easily and thus lead to the development of pathogenic processes (Gope *et al.*, 2017). Heavy metals can also originate from operating fluids released from vehicles into the street surface (Shi & Wang, 2013). Ongoing studies indicate increased content of trace elements in street dust in urban areas (Shi & Wang, 2013)). Such increased concentrations are observed particularly in the case of lead, cadmium, copper, chromium, and nickel as revealed by studies focus on big cities, characterized by a high intensity of motor vehicle traffic and the presence of industrial emitters (Zhao *et al.*, 2015). The study of the street dust is interesting because it is in close contact with the population than particulate matter (measured at 4 m above the ground) or soils. Heavy metal in the street dust can enter the human body through three routes of exposure; inhalation, Injection or dermal. Depending on factors such as toxicity of the element, bioavailability, concentration, among others, as well as socioeconomic issues and the person's health status, heavy metal can generate adverse health effects. (Calderon *et al.*, 2001, Carrizales *et al.*, 2006 and Amanambu, 2015).

Various methodologies have been employed to assess heavy metal pollution in street dust. Zhang *et al.* (2012) utilized magnetic and chemical methods to distinguish sources of anthropogenic heavy metals in urban dusts, providing a robust framework for source identification (Zhang *et al.*, 2012). Additionally, Yıldırım and Tokalıoğlu (2016) conducted a multivariate statistical analysis to explore heavy metal speciation in different grain sizes of contaminated dust, revealing that particle size plays a critical role in metal distribution and toxicity (Yıldırım & Tokalıoğlu, 2016).

MATERIALS & METHODS

Sample Collection

Loose dust samples were collected from three district arrears; Mechanic workshops (MWK), Motor Parks (MPK) and Roundabout/ Highways (RHW). This was achieved using small brush and dust pan. About 5 – 10 grams of representative accumulated dust were collected into a labeled sample jar. In order to prevent contamination, new glove was worn for each sample collection. Each sample was clearly labeled using date, location and sample ID. The samples were kept cool and protected from sunlight. The sampling was conducted in dry season to avoid heavy metals being washed by rain.

Analytical Method

The samples were prepared and processed at the Geochemistry and the Central Research Laboratory of The Polytechnic, Ibadan respectively. The process samples were analyzed using Induced Couple Plasma-Atomic Emission Spectrometry (ICP-AES) at PAM BEE analytical laboratory Ibadan. Dust samples (~0.5 g) were digested with concentrated HNO3, H2O2, and HCl using an open vessel method, diluted to 50 Ml, and then filtered. Heavy metal concentrations were determined by ICP-AES. Analytical quality was assured through reagent blanks, duplicates, spikes, and certified reference materials, with results expressed as mg/kg dry weight.

Statistical Analysis

The data from the study were examined statistically. The analysis of HM concentrations of street dust samples at various location resulted in the estimation of means and standard deviation (SD). A Microsoft Excel spreadsheet was used to do descriptive statistics on the data, as well as all contamination assessment tools (CF, PLI, and Igeo). The contamination factor (CF), the geo-accumulation index (Igeo), also known as the single factor pollution index (PI) and the pollution load index were all used to determine the level of metal contamination in the street dust samples.

Contamination Factor (CF)

The Contamination Factor (CF) is an index used to assess the level of contamination of HM in the dust samples. The CF of each metal under examination was determined using equation and soil quality criteria for environmental and human health protection. The baseline values were taken from the earth's crust (Rinklebe *et al.*, 2019).

$$CF_n = \frac{C_{sample}}{C_{background}}$$

Where CFn = contamination factor of each metal
Csample = determined metal concentrations,
Cbackground = metal background concentration
The CF is classified into four groups:
CF < 1: low concentration
1 < CF < 3: moderate concentration
3 < CF < 6: considerable contamination
CF > 6: very high contamination

Pollution load index (PLI)

The pollution level of HM in sampled street dust was calculated using the pollution level index (PLI) developed by Tomlinson *et al.*, 1980. PL reading of 1 or higher indicate pollution, value lower than 1 point to metal concentration that are close to background levels.CF has no units and represents the total or reciprocal pollution effects of all HM in a single overall contamination index

$$PLI = (CF1 \times CF2 \times CF3 \times \ldots \times CFn)^{\frac{1}{n}}$$

computed using Equation above.
PLI < 1 indicate perfection, no pollution or good site
PLI = 1 is considered a reference line when levels of pollutants are present
PLI > 1 is considered a worsening of site quality

Index of geo-accumulation (Igeo)
The index of geo-accumulation (Igeo) was introduce by Muller (1969) to assess the degree of heavy metal pollution by comparing current concentrations with pre-industrial level or background values.

$$I\,geo = \log_2 \frac{C_n}{1.5 \times B_n}$$

where Cn denotes the amount of a specific metal in the sample, and Bn denotes the metal's background concentration. To account for any differences in background values produced by lithological variances in the samples, a constant of 1.5 is applied.
The Contamination Factor (CF), Pollution Load Index (PLI), and Geo-accumulation Index (igeo) for all samples were calculated using typical background values (Ni:21, Cu:25, Pb:20, Fe:4700, Zn:90, Cr:70, Cd:0.1 mg/kg) and the obtained dust data.

RESULTS & DISCUSSION

Results: The results of the analysis are presented below (Table 1). Metal concentrations in dust were calculated on a dry weight basis and expressed in mg/kg.
Nickel (Ni) - The range of Nickel concentration is between 16.20 -122.50 mg/kg with mean values of 30.2 mg\kg for RHW, 51 mg/kg for MPK and 71.59 mg/kg for MWK (Table 2). The value of Ni concentration is more at Mechanic workshop MWK >MPK.> RHW.

Table 1: Element Concentrations of street Dust samples

Sample Number	Sample Identity	Ni mg/kg	Cu mg/kg	Pb mg/kg	Fe mg/kg	Zn mg/kg	Cr mg/kg	Cd mg/kg
IBDEC 02	RHW	35.35	ND	134.71	3654.43	110.82	ND	ND
IBDEC 21	RHW	20.81	103.24	ND	3717.81	45.49	8.33	ND
IBDEC 26	RHW	33.04	ND	ND	3529.97	94.98	ND	ND
IBDEC 34	RHW	31.66	ND	76.61	3573.08	103.79	ND	ND
IBDEC 05	MWK	ND	ND	89.15	2837.59	52.18	ND	ND
IBDEC 20	MWK	68.82	30.02	111.97	3499.3	176.67	36.73	ND
IBDEC 27	MWK	122.5	ND	74.79	319.62	153.18	27.76	ND
IBDEC 40	MWK	95.04	103.89	368.19	3311.44	484.85	60.52	ND
IBDEC 07	MPK	42.84	ND	70.74	3610.16	87.56	35.12	ND
IBDEC 18	MPK	55.49	ND	13.72	3945.51	95.34	40.49	ND
IBDEC 22	MPK	63.62	ND	164.79	3803.49	30.17	8.71	ND
IBDEC 29	MPK	42.05	ND	65.44	3707.38	50.11	15.82	ND

RHW - Roundabout / Highway
MWK - Mechanic Workshop
MPK - Motor Park

Table 2: Descriptive statistics of the total Concentration of HM (mg/kg) in Dust Particles (mg/kg)

Sample ID	Statistics	Ni	Cu	Pb	Fe	Zn	Cr	Cd
RHW	Maximum	35.35	103.24	134.71	3717.81	110.82	8.34	ND
	Minimum	20.81	ND	ND	3529.97	45.49	ND	ND
	Mean	30.20	25.81	52.82	3618.81	88.77	2.08	ND
	SD	6.45	51.62	66.21	83.77	29.56	4.16	ND
MWK	Maximum	122.50	103.89	368.19	3499.30	484.89	60.52	ND
	Minimum	ND	ND	74.79	319.62	52.18	ND	ND
	Mean	71.59	33.48	161.03	2491.99	216.72	31.25	ND
	SD	52.52	49.03	138.96	1474.77	186.73	25.00	ND
MPK	Maximum	63.62	ND	169.79	3945.51	95.34	40.49	ND
	Minimum	42.05	ND	13.72	3610.17	30.17	8.71	ND
	Mean	51.00	ND	78.67	3766.60	65.80	25.05	ND
	SD	10..43	ND	61.55	143.01	363.21	15.20	ND

Mechanic workshops have the highest values followed by Motor parks, indicating that Ni concentration is from vehicular activities. Excess concentration causes; Carcinogenic and negativity effects reproductive health (Genchi *et al.*, 2020), (Lu *et al.*, 2009).

Copper (Cu) - Copper was detected in 3 locations, one area at round about (Lagos/Ibadan Toll gate) and two areas at Mechanic workshops (Agodi gate and Olorunsogo Market). The range of the concentration is between 2.4 - 103.89 mg/kg. Mean values of 25.81 mg\kg for RHW and 33.48 mg/kg for MWK (Table 2). The Permissible limit of copper is 100 mg/kg (Mafuyai *et al.*, 2015, p.52), which means location 21(103.24 mg/kg) and location 40 (103.89 mg/kg) were slightly above the permissible limit, this may be due to the fact that these locations deals with heavy trucks and sales of vehicles spare parts. Cu is associated with corrosion of metallic vehicle parts, lubricants leakage, industrial and incinerator emission (Shi & Wang, 2013). Free copper instead of total serum copper has been found to be a possible risk factor for developing cognitive impairment in the study of mental decline patients (Salustri *et al.*,2010).

Lead (Pb) - Concentration ranges from 13.72 - 368.19 mg/kg. Mean values of 52.82 mg\kg for RHW, 78.67 mg/kg for MPK and 161.03 mg/kg for MWK (Table 2). From the chart the range is MWK.> MPK.> RHW. (Adeagbo, 1985), (Pagotto *et al.*, 2001). These authors observed that high concentration of Pb were due to high traffic densities in urban areas. The concentration is very high in locations 5, 20,2,22 and 40. The locations are 5 (Sango mechanic workshop), 20 (Olorunsogo market mechanic workshop), 2 (Secretariat roundabout), 22 (Challenge International Motor park and 40 (Agodi Mechanic workshop) which are above the permissible limit of 100 mg/kg (Poggio *et al.*, 2009). The pollution effect of Pb is found in all the arrears visited. Pb is one of the most dangerous heavy metals to both man and animal existence. It excesses leads to high blood levels, which can inhibit hemoglobin synthesis, causing; irritation, mental retardation, brain damage and tumor. (Lu *et al.*, 2009).

Iron (Fe) - The range of Fe concentration is 319.62 - 3944.51 mg/kg. Mean values of 3618.18 mg\kg for RHW, 3766.6 mg/kg for MPK and 2492.99 mg/kg for MWK (Table 2.). Fe has the highest concentration among all the metals analyzed and in high value in all the locations. This could be linked to a mix of soil re-suspension, as in the case of natural dust. Industrial activities and vehicular traffic such as brake wears, tire and road wear and exhaust from vehicles can contribute iron-containing particles. This is evidenced by the high average concentrations obtained from both Roundabouts/highways (RHW).and Motor parks (MPK) compared to Mechanic workshops (MWK). Natural weathering and wind erosion also release iron-rich minerals into dust. The concentrations of Fe were higher compared to some literature reports and this was due to the contribution of Fe from the weathering of the rocks in the area, in addition to several sources cited above. (Mafuyai *et al.*, 2015, p.52), Excess of Fe can cause conjunctivitis, (Ahumada *et al.*, 1999).

Zinc (Zn) - Zinc concentration is from 30.17 - 484.85 mg/kg. Mean values of 88.77 mg\kg for RHW, 65.8 mg/kg for MPK and 216.72 mg/kg for MWK (Table 2). Mean is MWK > RHW > MPK. IBEDC 40 (Agodi gate Mechanic Workshop) has values exceeding permissible limit. Zn concentrations are found high in the heavy traffic density and industrial areas (Genchi *et al.*, 2020).). High concentration of Zn leads to Neurological problems (Zheng *et al.*, 2010).

Chromium (Cr) - Chromium concentration ranges from 8.33 - 1514.72 mg/kg. Mean values of 2.08 mg\kg for RHW, 25.05 mg/kg for MPK and 31.25 mg/kg for MWK (Table 2). Range MWK > MPK > RHW. The mean concentration is far below the permissible limit. It concentration is mainly from natural sources (Hemati & Rahimi, 2020, P.22973). Excess of chromium can lead to chronic toxicity, bleeding of the gastrointestinal tract, cancer of the respiratory tract, ulcers of the skin and mucus membrane, (Coetzee *et al.*, 2020, P. 11/30), (Kimbrough *et al.*, 1999, P. 35). The permissible limit is 100 mg/kg (Lu *et al.*, 2009). Mechanic workshops and Motor parks are likely risk areas of Chromium contamination.

Discursion

The mean heavy metal concentration plot (Figure 3) provides an overview of all six detected metals across the three sampling sites. Iron (Fe) dominates overwhelmingly at all sites, dwarfing all other metals in concentration. Fe is consistently the most abundant metal in urban dust globally, reflecting both geogenic and anthropogenic inputs (Chen *et al.*, 2010). MPK records the highest mean Fe at 3766.60 mg kg^{-1}, followed closely by RHW at 3618.81 mg kg^{-1}, while MWK has the lowest mean Fe at 2491.99 mg kg^{-1}. This dominance of Fe is characteristic of urban road dust influenced by vehicular wear, industrial emissions, and soil resuspension (Thorpe & Harrison, 2008; Querol *et al.*, 2007). The near-invisibility of other metals at this scale underscores the need for exclusion of iron. Figure 4 depicts the mean concentrations excluding Fe (Trace Metals). With Fe removed, the true variability among trace metals becomes visible. MWK emerges as the most contaminated site across nearly all trace metals: Pb (161.03 mg kg^{-1}), Zn (216.72 mg kg^{-1}), Ni (71.59 mg kg^{-1}), and Cr (31.25 mg kg^{-1}) are all highest at MWK. This pattern strongly suggests proximity to industrial or heavy traffic sources at MWK. Cu was not detected at MPK, and Cd was absent at all sites. RHW shows moderate contamination across most metals, while MPK is relatively lower in trace metals despite its high Fe, suggesting Fe at MPK may be largely geogenic (natural soil origin) rather than anthropogenic.

The Minimum – Mean – Maximum Range chart (Figure 5) reveals the spread and variability of concentrations within each site for Ni, Pb, Zn, and Cr. The elevated concentrations of the metals in urban dust are strongly associated with industrial emission, vehicular exhaust, and tyre and brke wear (Hjortenkrans *et al.*, 2006;

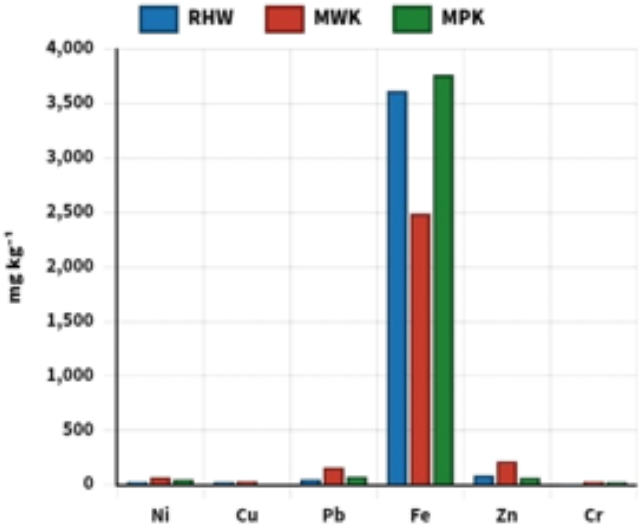


Figure 3: Mean Heavy Metal Concentrations by Site (mg kg^{-1})

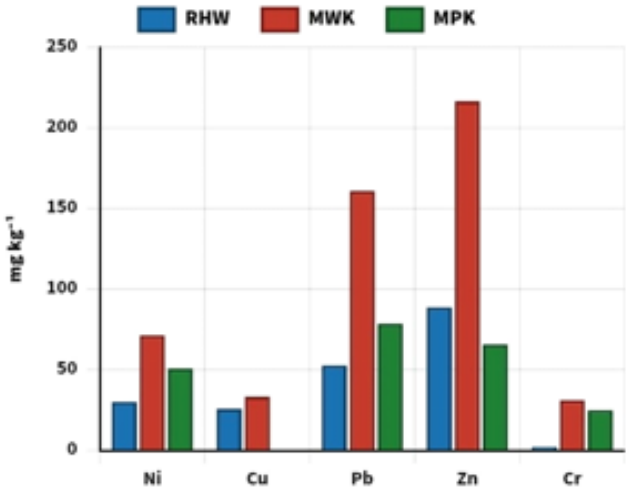


Figure 4: Meam Concentrations Trace Metals (mg kg^{-1})

Charlesworth *et al.*, 2003). Zn is a well-established tracer of tyre wear, while Pb is linked to historical leaded fuel use and industrial smelting (Councell *et al.*, 2004) MWK shows the widest ranges, particularly for Pb (74.79- 368.19 mg kg^{-1}) and Zn (52.18- 484.89 mg kg^{-1}), indicating highly heterogeneous contamination, some sampling points are far more polluted than others, pointing to localised hotspots within the site. RHW shows narrower ranges, suggesting more spatially uniform contamination. MPK has relatively tight ranges for most metals, consistent with a more homogeneous dust composition. The absence of Cu at MPK and Cd at all sites is consistent with findings in moderately urbanised environments with limited electroplating or battery industries (Li *et al.*, 2013). Wide min-max gaps at MWK are a public health concern, as peak exposures at hotspots could significantly exceed mean values. Wide concentration ranges within a single site reflect spatial heterogeneity driven by localised point sources and uneven traffic density (Werkenthin *et al.*, 2014). Hotspot contamination, where peak values greatly exceed means, is a recognised public health concern in dust exposure assessments (Laidlaw & Filippelli, 2008; Rasmussen *et al.*, 2013).

Radar or spider plots are widely used in environmental geochemistry to characterise site-specific contamination fingerprints and identify multi-source pollution (Lu *et al.*, 2009; Zheng *et al.*, 2010). The asymmetric polygon profiles observed at each site are indicative of mixed pollution sources, consistent with findings in comparable West African and developing-country urban environments (Soltani *et al.*, 2015; Kowalska *et al.*, 2018). The Normalised Radar Plot (Figure 6) normalises each metal to its global maximum across all sites, allowing direct comparison of contamination profiles regardless of absolute concentration. MWK has the largest radar polygon, confirming it as the most multi-metal contaminated site. Its profile extends far outward for Pb, Zn, Ni, and Cr simultaneously, indicating mixed pollution sources , likely a combination of vehicular traffic, industrial activity, and waste. RHW shows a

moderate, relatively balanced profile. MPK's polygon is notably smaller, confirming lower trace metal burdens despite high Fe. The asymmetry of each site's polygon reveals that no single source explains all contamination, multiple simultaneous inputs are likely operating.

Standard deviation (SD) by Metal and Site (Figure 7)

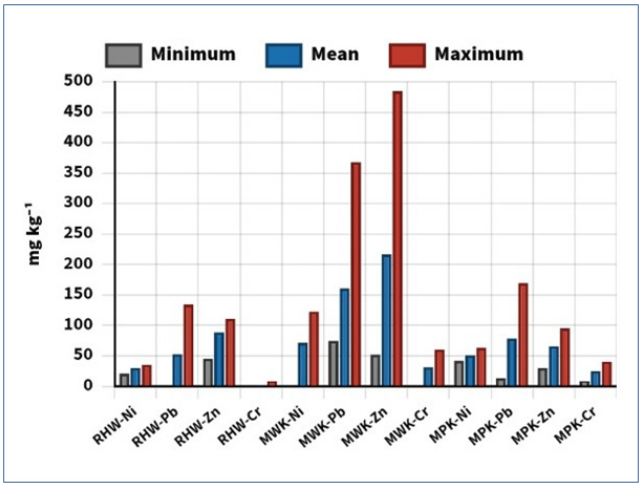


Figure 5: Range of Concentrations: Minimum, Mean and Maximum by Site (mg kg^{-1})

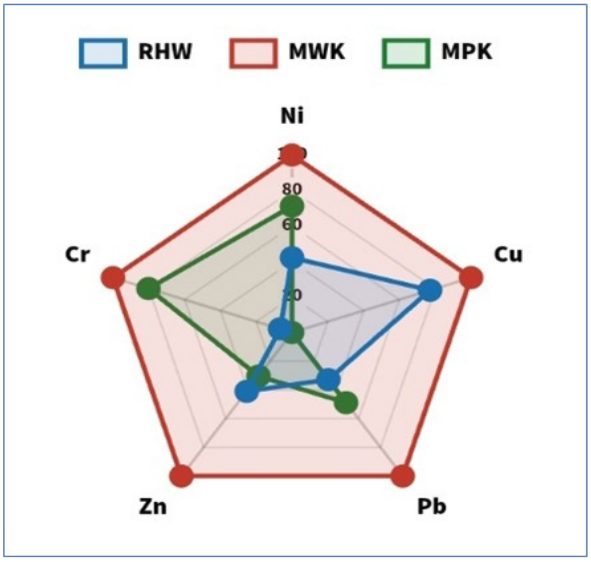


Figure 6: Normalized Site Contamination Fingerprint - Rader Plot (% of Max)

quantifies data dispersion around the mean. MWK consistently shows the highest SD across all metals, confirming the heterogeneity observed in Figure 5. The exceptionally high SD for Fe at MWK (1474.77 mg kg^{-1}) is particularly notable, nearly 60% of the mean, indicating massive spatial variability in iron deposition, possibly from point sources such as a nearby foundry, welding workshop, or scrap metal facility. Zn at MPK also shows a surprisingly high SD (363.21 mg kg^{-1}) relative to its mean (65.80 mg kg^{-1}), suggesting occasional but intense Zn inputs. High standard deviation relative to the mean is a statistical indicator of point-source influence in environmental contamination studies (Imperato *et al.*, 2003). Elevated Fe SD has been linked to proximity to foundries, welding workshops, and scrap metal processing facilities (Pant & Harrison, 2013). Anomalously high Zn SD has been attributed to episodic inputs from galvanised infrastructure and industrial runoff (Councell *et al.*, 2004; Adamiec *et al.*, 2016). RHW has the most consistent, low-SD profile, implying a stable and relatively uniform contamination source such as steady road traffic.

Iron (Fe) full statistics per Site (Figure 8) focuses on Fe, the dominant metal, comparing minimum, mean, and maximum values across all three sites. MPK has the highest maximum Fe (3945.51 mg kg^{-1}) and mean (3766.60 mg kg^{-1}), with a narrow min-max gap (3610.17–3945.51 mg kg^{-1}), strongly suggesting a consistent, uniform Fe source, most likely natural lithogenic (crustal) material (Querol *et al.*, 2007; Pant & Harrison, 2013) or consistent traffic-related corrosion. RHW shows a similarly tight range (3529.97–3717.81 mg kg^{-1}), supporting a stable source. MWK, by contrast, has the lowest mean Fe (2491.99 mg kg^{-1}) but the widest range (319.62–3499.30 mg kg^{-1}), a spread of over 3000 mg kg^{-1}, indicating highly erratic Fe inputs, possibly reflecting episodic industrial discharges superimposed on background levels, a pattern documented in several Sub-Saharan African industrial corridors (Nwachukwu *et al.*, 2010; Addo *et al.*, 2012).

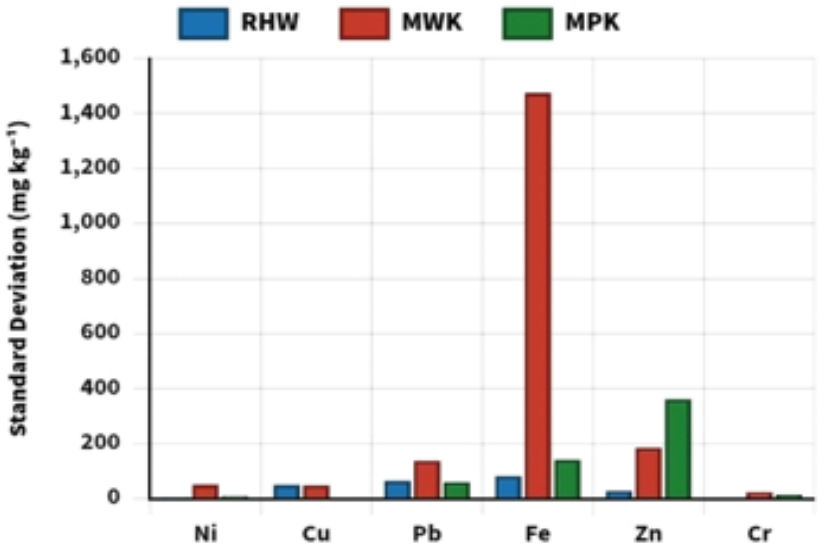


Figure 7: Standard Deviation of Heavy Metal Concentrations by Site

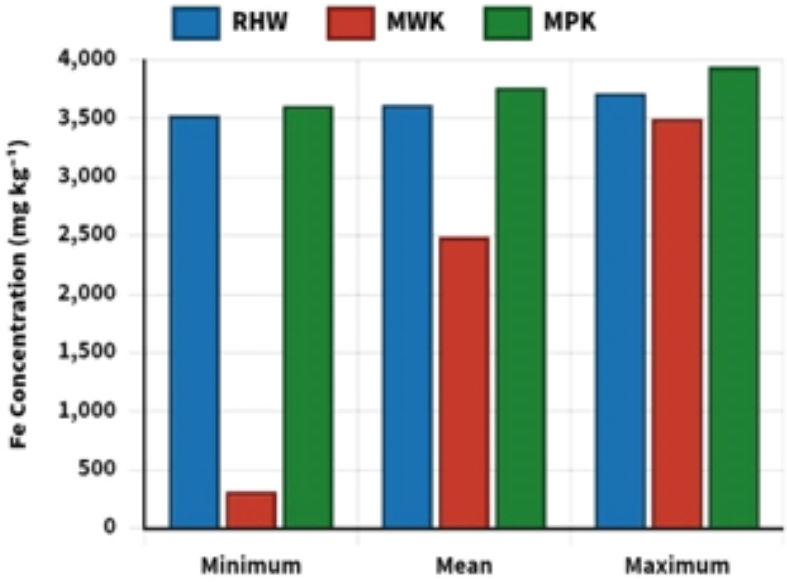


Figure 8: Iron (Fe) Concentrations Statistics per Sampling Site

Contamination Status of Heavy Metals in Dust Samples

The levels of heavy metals in the dust samples were assessed using the contamination factor (CF), geo-accumulation index (Igeo), and the pollution load index (PLI). To put the results into context, the average values were compared with the background concentrations suggested by Turekian and Wedepohl (1961). The CF values showed that the metals behaved differently in terms of enrichment. Nickel (≈0.82), copper (≈0.19), iron (≈0.08), and cadmium (≈0.00) all fell in the low-contamination range, suggesting that these elements are mostly from natural sources rather than human activities. Zinc (≈1.75) and chromium (≈1.41) showed moderate contamination, pointing to some influence from human activities. The standout element was lead (≈3.35), which reached the "considerable contamination" level. This strongly suggests anthropogenic inputs, most likely from vehicle emissions, industrial discharge, or the legacy effect of leaded petrol. The Igeo values largely supported the CF findings. Nickel, copper, iron, and cadmium all fell in the unpolluted category. Zinc was classified as unpolluted to moderately polluted, while chromium remained unpolluted overall. On the other hand, lead stood out again, with an Igeo value of about 1.3, placing it in the moderately polluted category. The overall PLI for the study area was 0.72, which is below 1. This means that, in general, the dust samples are not heavily polluted (Table 3). However, the relatively high values for Pb, and the moderate values for Zn and Cr, suggest that there are specific spots where contamination is more noticeable and may require attention.

Table 3: Contamination level of different HMs in dust depending on CF, PLI, and Igeo values.

Metal	Avg CF	Contamination Level	Avg Igeo	Igeo Pollution Class
Ni	~0.82	Low contamination	-0.29	Unpolluted
Cu	~0.19	Low contamination	-3.0	Unpolluted
Pb	~3.35	Considerable contamination	1.3	Moderately polluted
Fe	~0.08	Low contamination	-5.2	Unpolluted
Zn	~1.75	Moderate contamination	0.22	Unpolluted–Moderately polluted
Cr	~1.41	Moderate contamination	-0.68	Unpolluted
Cd	~0.00	Low contamination	-∞ (all ND)	Unpolluted

CONCLUSION

This study assessed the contamination status of heavy metals in street dust from different locations within Ibadan metropolis. The results demonstrated that Pb was the dominant contaminant, reaching levels of considerable contamination (CF ≈ 3.35; Igeo ≈ 1.3), followed by moderate enrichment of Zn and Cr. Ni, Cu, and Fe remained within the low contamination range, suggesting primarily natural inputs with minimal anthropogenic influence. The overall PLI value (<1) indicates that, on average, the study area is not heavily polluted. However, localized hotspots, particularly around mechanic workshops and motor parks, present elevated risks. MWK consistently emerges as the most contaminated and most spatially variable site, warranting priority attention for environmental remediation and public health intervention. MPK and RHW show elevated Fe likely of geogenic or steady traffic origin, but are comparatively lower in toxic trace metals. The identification of MWK as a priority remediation site is consistent with risk-based frameworks for heavy metal contamination in urban environments (Laidlaw & Filippelli, 2008; Men *et al.*, 2018). The contamination pattern followed the order: Pb > Zn > Cr > Ni > Cu > Fe, with Pb clearly emerging as the most concerning pollutant due to its toxicity and persistence. The findings underscore the need for continuous monitoring of heavy metals in urban dust, particularly Pb, which remains a significant environmental hazard. Although the overall pollution load index suggests acceptable site quality, the considerable contamination of Pb points to localized anthropogenic sources that should be addressed through stricter environmental management and control measures. These results collectively suggest that anthropogenic activities, particularly industrial operations and heavy vehicular traffic, are the dominant drivers of heavy metal loading in dust at these sites.

REFERENCES

Abbasi, S., Turner, A., & Kelly, F. J. (2017). Tackling the plastics problem: Heavy metal content of household, commercial and industrial plastic products sold on the UK market. *Environmental Pollution, 231*(1), 807–814. https://doi.org/10.1016/j.envpol.2017.08.024.

Adamiec, E., Jarosz-Krzemińska, E., & Wieszała, R. (2016). Heavy metals from non-exhaust vehicle emissions in urban and motorway road dusts. *Environmental Monitoring and Assessment, 188*(6), 369. https://doi.org/10.1007/s10661-016-5377-1

Adelekan, B. A. (2016). Determination of some heavy metals in roadside dust in Ibadan, Nigeria. *Journal of Applied Sciences and Environmental Management, 20*(4), 1047–1055. https://doi.org/10.4314/jasem.v20i4.26.

Addo, M. A., Darko, E. O., Gordon, C., Nyarko, B. J. B., & Gbadago, J. K. (2012). Heavy metal concentrations in road deposited dust at Ketu-south district, Ghana. *International Journal of Science and Technology, 2*(1), 28–39.

Al-Khashman, O. A. (2004). Heavy metal distribution in dust, street dust and soils from the work place in Karak Industrial Estate, Jordan. *Atmospheric Environment, 38*(39), 6803–6812. https://doi.org/10.1016/j.atmosenv.2004.09.011.

Amanambu, A. C. (2015). Health risk assessment of heavy metals in street dust of an urban environment in Nigeria. *Environmental Monitoring and Assessment, 187*(1), 4171. https://doi.org/10.1007/s10661-014-4171-y.

Ashrafi, S. D., Kamani, H., & Jaafari, J. (2014). Heavy metals contamination and distribution in street dusts of Tehran. *Environmental Earth Sciences, 72*(9), 3293–3303. https://doi.org/10.1007/s12665-014-3224-0.

Basart, S., Pérez, C., Cuevas, E., Baldasano, J. M., & Gobbi, G. P. (2016). Aerosol characterization in Northern Africa, Northeastern Atlantic, Mediterranean Basin and Middle East from direct-sun AERONET observations. *Atmospheric Chemistry and Physics, 9*(21), 8265–8282. https://doi.org/10.5194/acp-9-8265-2009.

Burgos, A., Moreno, T., Querol, X., de la Rosa, J. D., & Gibbons, W. (2008). Airborne trace element pollution in an industrialised city: Human health risks. *Journal of Environmental Monitoring, 10*(10), 1226–1236. https://doi.org/10.1039/B808815M.

Calderón, J., Navarrete, B., & Jiménez, J. (2001). Exposure to heavy metals in street dust: A biomonitoring approach. *Science of the Total Environment, 281*(1–3), 79–87. https://doi.org/10.1016/S0048-9697(01)00818-4.

Carrizales, L., Razo, I., Téllez-Hernández, J. I., Torres-Nerio, R., Torres, A., Batres, L. E., Cubillas, A. C., & Díaz-Barriga, F. (2006). Exposure to arsenic and lead of children living near a copper-smelter in San Luis

Potosí, Mexico: Importance of soil contamination for exposure of children. *Environmental Research, 101*(1), 1–10. https://doi.org/10.1016/j.envres.2005.07.010

Charlesworth, S., De Miguel, E., & Ordóñez, A. (2011). A review of the distribution of particulate trace elements in urban terrestrial environments and its application to considerations of risk. *Environmental Geochemistry and Health, 33*(2), 103–123. https://doi.org/10.1007/s10653-010-9325-7

Chen, H., Lu, X., Li, L. Y., Gao, T., & Chang, Y. (2014). Metal contamination in campus dust of Xi'an, China: A study based on multivariate statistics and spatial distribution. *Science of the Total Environment*, *484*, 27–35. https://doi.org/10.1016/j.scitotenv.2014.03.026

Christoforidis, A., & Stamatis, N. (2009). Heavy metal contamination in street dust and roadside soil along the major national road in Kavala's region, Greece. *Geoderma, 151*(3–4), 257–263. https://doi.org/10.1016/j.geoderma.2009.04.016.

Councell, T. B., Duckenfield, K. U., Landa, E. R., & Callender, E. (2004). Tire-wear particles as a source of zinc to the environment. *Environmental Science & Technology, 38*(15), 4206–4214. https://doi.org/10.1021/es034631f

Dada, S. S. (2006). Proterozoic evolution of Nigeria. In O. A. Oshin (Ed.), *Geology and Mineral Resources of Nigeria* (pp. 29–44). NAPE Bulletin.

Ebrahimi, A., Kalantari, N., & Abbaspour, M. (2020). Human health risk assessment of heavy metals in urban dust of Tehran, Iran. *Environmental Science and Pollution Research, 27*(24), 29944–29956. https://doi.org/10.1007/s11356-020-09453-8.

Gope, M., Saha, N., & Sanyal, S. (2017). Characterization and health risk assessment of heavy metals in street dust of Asansol, India. *Environmental Earth Sciences, 76*(12), 419. https://doi.org/10.1007/s12665-017-6767-3.

Hemati, M., & Rahimi, E. (2020). Chronic exposure to heavy metals in street dust: Potential health risks for children and adults. *Ecotoxicology and Environmental Safety, 195,* 110496. https://doi.org/10.1016/j.ecoenv.2020.110496.

Hjortenkrans, D. S. T., Bergbäck, B. G., & Häggerud, A. V. (2006). New metal emission patterns in road traffic environments. *Environmental Monitoring and Assessment, 117*(1–3), 85–98. https://doi.org/10.1007/s10661-006-7706-2

Imperato, M., Adamo, P., Naimo, D., Arienzo, M., Stanzione, D., & Violante, P. (2003). Spatial distribution of heavy metals in urban soils of Naples city (Italy). *Environmental Pollution, 124*(2), 247–256. https://doi.org/10.1016/S0269-7491(02)00478-5

Khademi, H., Gabarrón, M., Abbaspour, A., Martínez-Martínez, S., Faz, A., & Acosta, J. A. (2019). Environmental impact assessment of heavy metals in street dust and road-deposited sediment: A review. *Environmental Geochemistry and Health, 41*(2), 939–956. https://doi.org/10.1007/s10653-018-0193-5.

Kowalska, J. B., Mazurek, R., Gąsiorek, M., & Zaleski, T. (2018). Pollution indices as useful tools for the comprehensive evaluation of the degree of soil contamination — A review. *Environmental Geochemistry and Health, 40*(6), 2395–2420. https://doi.org/10.1007/s10653-018-0106-z

Laidlaw, M. A. S., & Filippelli, G. M. (2008). Resuspension of urban soils as a persistent point source of lead poisoning in children. *Applied Geochemistry, 23*(8), 2344–2356. https://doi.org/10.1016/j.apgeochem.2008.05.009

Lu, X., Wang, L., Li, L. Y., Lei, K., Huang, L., & Kang, D. (2010). Multivariate statistical analysis of heavy metals in street dust of Baoji, NW China. *Journal of Hazardous Materials, 173*(1–3), 744–749. https://doi.org/10.1016/j.jhazmat.2009.09.001

Men, C., Liu, R., Xu, F., Wang, Q., Guo, L., & Shen, Z. (2018). Pollution characteristics, risk assessment, and source apportionment of heavy metals in road dust in Beijing, China. *Science of the Total Environment,* 612, 138–147. https://doi.org/10.1016/j.scitotenv.2017.08.123

Nwachukwu, M. A., Feng, H., & Achilike, K. (2010). Integrated studies for automobile wastes and vehicular pollution management in developing countries. *Environmental Geochemistry and Health, 32*(3), 191–214. https://doi.org/10.1007/s10653-009-9267-2

Pant, P., & Harrison, R. M. (2013). Estimation of the contribution of road traffic emissions to particulate matter concentrations from field measurements: A review. *Atmospheric Environment, 77*, 78–97. https://doi.org/10.1016/j.atmosenv.2013.04.028

Querol, X., Alastuey, A., Moreno, T., Viana, M. M., Castillo, S., Pey, J., ... & Artiñano, B. (2008). Spatial and temporal variations in airborne particulate matter (PM10 and PM2.5) across Spain 1999–2005. *Atmospheric Environment, 42*(17), 3964–3979. https://doi.org/10.1016/j.atmosenv.2006.10.071

Rasmussen, P. E., Beauchemin, S., Chenier, M., Levesque, C., MacLean, L. C. W., Marro, L., ... & Gardner, H. D. (2011). Canadian house dust study: Population-based concentrations, loads and loadings of arsenic, cadmium, chromium, copper, nickel, lead, and zinc inside urban homes. *Science of the Total Environment, 409*(22), 4885–4897. https://doi.org/10.1016/j.scitotenv.2011.07.033

Tang, R., Ma, K., Zhang, Y., & Mao, Q. (2017). The spatial characteristics and health risk assessment of heavy metals in street dust of urban areas in China. *Science of the Total Environment, 580*, 1363–1374. https://doi.org/10.1016/j.scitotenv.2016.12.096.

Thorpe, A., & Harrison, R. M. (2008). Sources and properties of non-exhaust particulate matter from road traffic: *A review. Science of the Total Environment, 400*(1–3), 270–282. https://doi.org/10.1016/j.scitotenv.2008.06.007

Turekian, K. K., & Wedepohl, K. H. (1961). Distribution of the elements in some major units of the Earth's crust. *Geological Society of America Bulletin,*

72(2), 175–192. https://doi.org/10.1130/0016-7606(1961)72[175:DOTEIS]2.0.CO;2.

Werkenthin, M., Kluge, B., & Wessolek, G. (2014). Metals in European roadside soils and soil solution — A review. *Environmental Pollution*, *189*, 98–110. https://doi.org/10.1016/j.envpol.2014.02.025

Yıldırım, D., & Tokalıoğlu, Ş. (2016). Source apportionment of heavy metals in street dusts of Kayseri, Turkey. *Atmospheric Pollution Research, 7*(2), 309–319. https://doi.org/10.1016/j.apr.2015.10.012.

Zhang, C., Qiao, Q., Appel, E., & Huang, B. (2012). Discriminating sources of anthropogenic heavy metals in urban street dusts using magnetic and chemical methods. *Journal of Geochemical Exploration, 119–120,* 60–75. https://doi.org/10.1016/j.gexplo.2012.06.014.

Zheng, N., Liu, J., Wang, Q., & Liang, Z. (2010). Health risk assessment of heavy metal exposure to street dust in the zinc smelting district, northeast of China. *Science of the Total Environment, 408*(4), 726–733. https://doi.org/10.1016/j.scitotenv.2009.10.075