

Assessment of Heavy Metals Contamination of Topsoil and Street Dust around Cement Factory in Southern Jordan

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Abstract

Evaluation of assessment of the metal processes governing the metals distribution in soil and dust samples is very significant and protects the health of human and ecological system. Recently, special attention has given to the assessment of metals pollution impact on soil and dust within industrial areas. This study aims to assess the metal contamination levels in the topsoil and street dust around the cement factory in Qadissiya area, southern Jordan. The levels of seven metals (namely Fe, Zn, Cu, Pb, Cr, Cd, and Mn) were analyzed using Flame Atomic Absorption Spectrophotometer (FAAS) to monitor, evaluate, and to compare topsoil and road dust pollution values of metals of the different types of urban area. The physicochemical parameters which believed to affect the mobility of metals in the soil of the study area were determined such as pH, EC, TOM, CaCO₃ and CEC. The levels of metal in soil samples are greater on the surface but decrease in the lower part as a result of the basic nature of soil. The mean values of the metals in soil can be arranged in the following order: Zn > Pb > Mn > Fe > Cu > Cr > Cd. The relatively high concentration of metals in the soil sample was attributed to anthropogenic activities such as traffic emissions, cement factory and agricultural activities. Correlation coefficient analysis and the spatial distribution of indices and the results of statistical analysis indicate three groups of metals: Fe and Mn result by natural origin, Zn, Pb, Cu and Zn result by anthropogenic origin (mainly motor vehicle traffic and abrasion of tires) while Cd is mixed origin. The higher content level values of metals of anthropogenic source in soil samples indicate that it is a source of contamination of air in the studied area.

Keywords

Cement Dust, Heavy Metals Contamination, Risk Assessment, Statistical Analysis, Jordan

1. Introduction

Trace element are one of the major sources of the environmental contamination, since they have a significant effect on its components of ecosystem which contribute to atmospheric contamination, that considered as the major environmental issue in many countries [1] [2] [3] [4]. The metals have been widely distributed in different environmental samples because of their significant impacts on ecological quality [2] [5]-[10]. The influence of anthropogenic activity as a major source of metal pollution either in the ecosystem was found by many studies which have been performed on heavy metals round the world during the recent decades [1] [2] [4] [5] [8] [11]-[31]. The contribution of metals to environmental pollution is from agricultural, mining processes and industrial activities beside automobile emissions. Street dusts and topsoil in the industrial areas are indicators of metal contamination from atmospheric deposition that receives varying inputs of industrial plants residential, energy production, fossil fuel burning, vehicular exhaust and particulate emission, vehicle wear air borne and resuspension of soil polluted [6] [23] [32] [33] [34]. Heavy metals can accumulate in the street dust and topsoil from atmospheric deposition by interception and sedimentation [35]. Ahmed and Ishiga [36] study that increases in anthropogenic trace metals in the environment can be attributed to the rapid industrialization and urbanization and increase in emissions to the atmosphere. Another study published by Al-Khashman and Shawabkeh [1] showed that the lead, zinc and cadmium have the highest level in area close to the cement factory while the value of chromium was low.

The mobilization of metals into the atmosphere by industrial activities has become an important process in the geochemical cycling of these metals [1] [33] [37]. Cement factories are important sources of emissions contain inorganic and organic pollutants and produce an input of metals [38]. The pollutants are emitted at all stages of the industrial process which includes extraction of the raw materials, drilling, crushing, producing and industrial processing [39]. Previous studies have investigated the impact of cement dust from the cement industry on soil and plant properties. Al-Khashman and Shawab-keh [1] studied the metal distribution in soils around the cement factory in southern Jordan and found that all of the metals were concentrated on the topsoil surface and the highest levels were found close to the cement factory. Arpita and Mitko [40] studied the topsoil near the cement factory in Rockfort, Kingston, Jamaica and found that topsoil is enriched with Pb, Zn, Cr, Cd, V, and Hg which are released into the air from cement kilns. Okoro *et al.* [41] studied the assessment of heavy metals

contents in the soil around a cement factory in Ewekoro, Nigeria and found that all the concentration of metals in the soil samples were measured that decrease as the distances of the society increased a way from cement factory. The main goal of this study is to determine the environmental impact caused by air emissions from the cement industry beside a residential area with no other industrial air contamination sources and to assess pollution values of metal in the topsoil and street dust samples that were collected at various sites in the study area, and to identify their natural or anthropogenic metals sources. In future, other parameters such as organic materials, pesticides, insecticides and trace metals in soil samples will be considered.

2. Materials and Methods

2.1. The Study Area

The study area was located in the southern part of the Jordan. The cement factory is situated 5 km northeastern of Qadissiya area (**Figure 1**), and it was located between $30^{\circ}50'N$ and $35^{\circ}36'E$. It is approximately 180 km away from the capital Amman, with an elevation about 1446 m. The investigated area has a

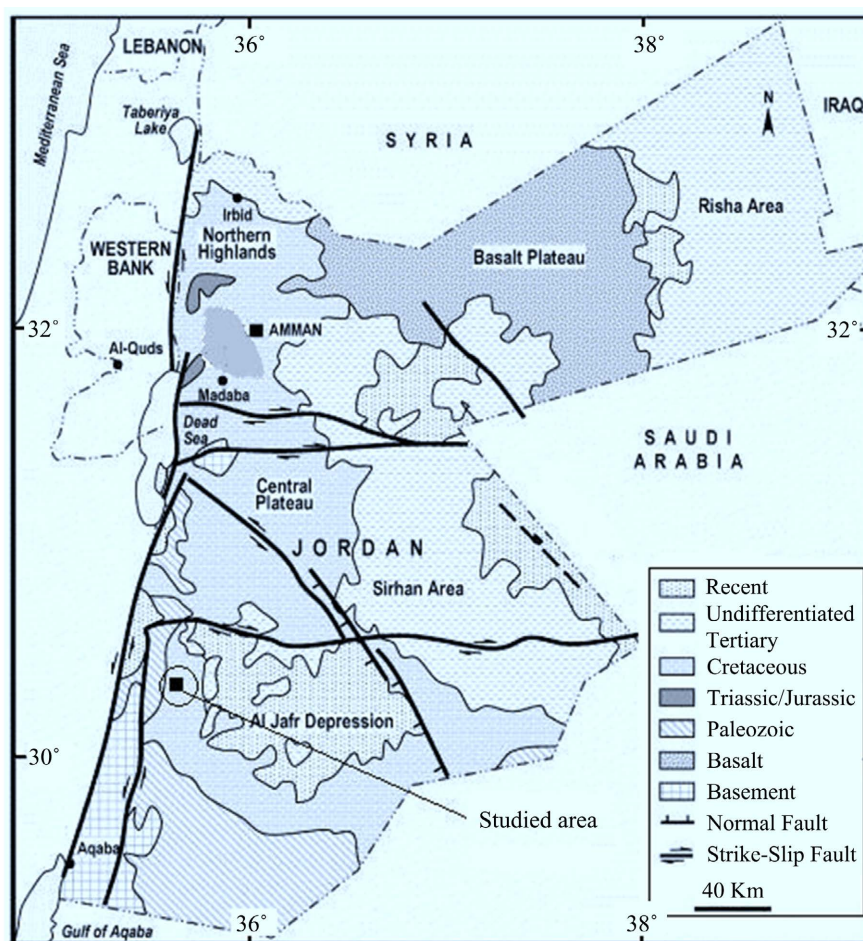


Figure 1. Location map of the studied area.

Mediterranean climate characterized by hot and dry in summer and cool in winter season. Mean minimum temperature in the investigated area were 1.2°C in January and 25.2°C in July (Department of Meteorology [42]). Rainfall occurs only in the winter season which was extended from November to April. It is precipitation was around (205 mm·yr⁻¹). Snowfall occurs occasion-ally, mainly in the western part of the study area in January to March. The mean number of snow days was 5 per year and the maximum recorded annual snowfall was 20 cm to 35 cm. The predominant wind direction is from westerly to northwesterly. The soil was yellow-brown with calcareous concretions. It was composed of loess-like silt and residual calcareous bed rock. The soil texture shows that it was sandy clay, which composed of sand (50%), clay (30%) and silt (20%). Upper cretaceous carbonaceous facies dominated in the central part of country, whereas ancient basement (Pre-Cambrian) and Cambrian Nubian sandstone dominated in the south part of the country. Basalt desert is dominated in northeastern parts and the rift valley forming Jordan's western borders. The investigated area was dominated by Amman Silicified Limestone Formation from the Campanian age. This formation consists of limestone, chert, massive chalky and marl [1] [43] [44]. This factory plays a significant role in the local economy. It was established 1984 as a state owned enterprise and was a major employer in the area. The factory was situated on the edges of the southern mountainous desert of the Wadi Araba site [1].

2.2. Sample Collection

In August 2023 the sixty-two composite soil samples were taken in a grid system around the cement factory at two depths: 0 - 10 cm and 10 - 20 cm. The samples were most densely collected around the cement factory and became less densely collected with increasing distance from the cement factory [1]. Wood, foreign objects and stones were removed in the field by hand and to avoid the effect due to differential uptake of metals by vegetation, sampling were increased in the non-agricultural sites is carried out at sites where plants with superficial roots were not present [38] [45]. All samples were collected with a stainless steel spatula and kept in plastic bags at room temperature for not more than one day from starting analytical procedures. Eighty-eight samples of street dust were collected from seven locations in the study area under stable weather condition. The sampling data are chosen at the end of the dry summer season after four rainless months. The samples were classified into seven areas *i.e.*, high traffic, moderate traffic, light traffic, schools and gardens, residential, parks and background sites (control) out of the investigated area (Table 1). A sampling point within each unit was collected at random, and approximately 250 g of the dust particles that had accumulated on impervious surface (street pavement) within a 5-m radius circle around the sampling sites [46] [47]. The dust sampling was carried out from pavement edges using a plastic dustpan and brushes, but they are not collected from sites adjacent to sites-specific pollution sources (e.g. gasoline stations and industrial sites). However, the samples were collected from

Table 1. Description of sampling areas. N number of samples, N = 88 samples.

Site	Location/sample point	Sample Code	N	Traffic load	Population load
A	High traffic (around Plant)	HT1-HT15	15	Heavy	Dense
B	Moderate traffic (city center)	MT1-MT15	15	Heavy	Dense
C	Light traffic (minor streets)	LT1-LT18	18	Low	Sparse
D	Residential streets	R1-R 30	30	Medium	Dense
I	Background sites (control)	BG1-BG10	10	Low	Sparse

both sides of the street on a dry day using a plastic dustpan and brush. About 250 g of dust was stored in small self-sealing plastic bags after being screened through a 2-mm plastic sieve to remove extraneous matter such as paving stone, small pieces of brick and other large debris [5] [6] [32] [46] [48] [49]. Background samples (n = 10) were collected from the remote sites outside the study area that were not affected by any source of contamination (control samples). The aim of these samples is for comparison purpose.

2.3. Analysis Preparation

The samples (dust and soil) were transferred from the collectors to quartz crucible dried at 105°C for about four hours to constant mass. The dried samples were then sieved through a 2-mm plastic sieve to remove unwanted gravel-sieved matter [1] [5] [32] [49]. Two grams of dried dust and soil were accurately weighted digested with 10 ml of concentration of HNO₃ solution in a test tube and left overnight. The final extracts were filtered into a 25 ml at 90°C. The final extracts were filtered into a 25 ml polyethylene volumetric flask through 0.45 µm filters and then dilute to the mark with 1% HNO₃ solution. The chemistry characteristics were determined following standard procedure [6] [49] [50] [51] [52] [53]. The pH was determined by mixing 1:2.5 (w/v) soil-distilled water suspensions [52]. Electrical conductivity (EC) was determined in 1:5 extra, calcium carbonate equivalent was determined by a manometric method [34]. The percentage of organic matter was determined by the titration method which is based on the oxidation of organic matter by K₂Cr₂O₇ [51] [53]. The value of cation exchange capacity (CEC) is obtained by calculation from exchangeable cations contents determined by measuring the solution content after treatment of five grams taken from the less than 63-µm soil fraction with sodium acetate and ammonium acetate solution [22] [50]. A flame atomic Absorption Spectrophotometer (Shimadzu AAS model AA-6200, Japan) was used to analyze heavy metals in the standard metal solutions (Merck Company, Germany) alongside the street dust and soil samples solutions. All the standard solution was prepared from analytical grade compounds of Merck Company. For the metals (Cu, Fe,

Cd, Pb, Zn, Cr and Ni) seven standard solutions of different concentrations are prepared in 2 M HNO₃, within the linear concentration range for measured. The calibration curve was prepared for each of the metals investigated by least square fitting. The accuracies of this method have been evaluated by analysis a standard reference material (SRM) from the International Atomic Energy Agency (IAEA) soil 7. The Selective Reaction Monitoring (SRM) analysis showed that the accuracy is better than $\pm 5\%$. The precision of the results was evaluated through replicate analysis (three replicates for each sample) [8] [14]. All glassware was Pyrex washed several times with soap, distilled water and diluted nitric acid to remove any adhered impurities.

3. Results and Discussion

3.1. Metals Distribution in Topsoil

3.1.1. Physico-Chemical Parameters

The physicochemical parameters of soil around the cement factory were given in **Table 2**. The mean pH values were acidic varying over a wide ranged from 6.33 - 8.16, which was suggests neutral to sub alkaline conditions for the soil samples. The average pH of the upper part (10 - 20 cm) of soil was 7.35, but in the lower part (0 - 10 cm) of soil was (7.66). The study area shows that the upper part of the soil was highly enriched with metals than the lower part (**Figure 2**). This might be attributing to the mobility of metals which is strongly influenced by many factors such as pH, Eh and the solubility of minerals. The highest pH values were attributed to the high content of carbonate, ash and cinder of anthropogenic source [20] [54] [55] which is neutralization of soil acidity, but the lower value for pH was found in the central area where there was high traffic density. The soil pH was 6.50 at 5 km. Distance which increased gradually to 6.77 at 2 km, and it was 7.77 at 500 m distance from cement factory. There was significant increase in the soil pH up to the distance of 1 km from the cement factory. These

Table 2. Mean, standard deviation, and range for the physicochemical parameters of the 62 soil samples at two depths.

Parameters	0 - 10 cm			10 - 20 cm		
	Mean	St. dev.	Range	Mean	St. dev.	Range
pH	7.66	0.37	6.73 - 8.16	7.35	0.49	6.33 - 8.07
EC ($\mu\text{s}/\text{cm}$)	941.15	77.56	695 - 1003	913.06	94.18	685 - 1033
TOM %	1.81	0.47	0.98 - 3.21	1.21	0.49	0.33 - 2.1
CaCO ₃ %	13.98	2.38	8.36 - 17.32	10.70	1.78	7.23 - 13.3
CEC %	63.18	22.34	42 - 120	80.05	15.31	50.12 - 102.33
Sand %	44.21	7.15	35.41 - 60.32	46.22	10.33	39.55 - 68.54
Silt %	26.51	4.19	20.13 - 32.44	24.33	8.44	19.65 - 37.22
Clay %	29.30	5.66	18.22 - 38.55	28.66	7.12	12.33 - 36.51

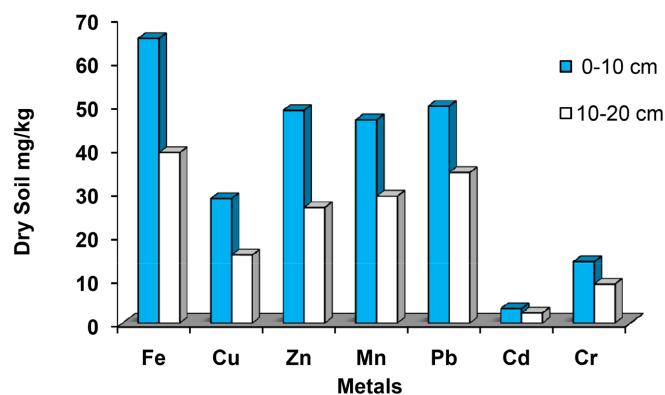


Figure 2. Mean value of metal concentrations in lower and upper soils.

results were in agreement with other researchers [56] [57] [58]. The electrical conductivity (EC) of the upper soil samples ranges from 685 - 1033 $\mu\text{s}/\text{cm}$ with an average value of 913.06 $\mu\text{s}/\text{cm}$, and in the lower part of soil it ranges from 695 - 1003 $\mu\text{s}/\text{cm}$ with an average value of 941.15 $\mu\text{s}/\text{cm}$. However, the high electrical conductivity values were measured close to the cement factory with increasing values in the residential area. Total organic matter (TOM %) content of the soil varied as 0.33 - 2.1, with a mean of 0.49 in the upper part of soil, but in the lower part of soil it ranges from 0.98 - 3.21, with an average value of 1.81 (Table 2). The mean value of the organic matter shows that the organic matter content in the soil around the cement factory is generally low. This result agrees with the results of Wufem *et al.* [59] and Balasubramanian *et al.* [60]. Low organic matter may also suggest probably a reflection of low annual vegetation and biomass production around the cement factory. Cation exchange capacity (CEC) in the upper soil ranges from 50.12 - 102.33, with mean value of 80.05, but in the lower part of soil it ranged from 42 - 120, with mean value of 63.18. Low CEC may result in the low buffering capacity of the soil and low nutrient retention, which reflects the reduce crop yield in the study area [59]. Usually pH influences the CEC of soil content, which in turn affect metals distribution and mobility in soil. Moreover, CaCO_3 content of the soil samples vary from 7.23 - 13.3 in the upper part of soil, with mean value of 10.70, but in the lower part it ranges from 8.36 - 17.32, with mean value of 13.98.

3.1.2. Metal Concentration in Topsoil

Analytical results of the concentrations of metals in the topsoil were summarized in Table 3. Based on the results of analysis for the metals (Cu, Fe, Cd, Pb, Zn, Cr and Ni) observed that metals originating from anthropogenic activities were distributed in topsoil by the atmospheric deposition within a distance depending on the grain size particles of the dust, direction and strength of wind, type of soil and major physico-chemical parameters such as pH, EC, and CEC of soil. Lead value in the lower soil (0 - 10 cm) samples ranged from 12.36 - 82.13 $\text{mg}\cdot\text{kg}^{-1}$ dry soil, with a mean value being of 47.92 $\text{mg}\cdot\text{kg}^{-1}$ dry soil. The highest value of lead is 82.13 $\text{mg}\cdot\text{kg}^{-1}$ measured in the upper soil samples collected from eastern side

Table 3. Mean, Standard deviation, and range for the metal contents ($\text{mg}\cdot\text{kg}^{-1}$) of the 62 soil samples at two depths.

Parameters	0 - 10 cm			10 - 20 cm		
	Mean	St. dev.	Range	Mean	St. dev.	Range
Cu	4.01	1.43	1.44 - 6.56	1.67	0.62	0.85 - 2.88
Fe	14.81	8.32	3.45 - 26.33	18.38	5.43	9.66 - 28.68
Zn	48.81	11.49	25.32 - 74.35	19.32	9.37	6.55 - 39.33
Mn	37.65	14.30	19.56 - 66.33	37.57	14.65	19.31 - 66.01
Pb	47.92	20.32	12.36 - 82.13	28.77	13.52	7.88 - 48.65
Cd	3.36	4.16	1.06 - 16.35	6.06	2.01	2.72 - 8.69
Cr	13.20	3.78	6.35 - 19.65	7.91	3.46	0.97 - 12.65

of the entrance and northeastern area of the cement factory (**Figure 2**). However, the lower lead concentration $12.36 \text{ mg}\cdot\text{kg}^{-1}$ was measured in the upper reference soil samples in the western side of cement factory. The high lead level in soil samples beside the cement factory can be attributed to the cement industry in which the process and production of cement industry require a substantial amount of energy supplied by burning fossil fuel and heavy traffic activity in and around the cement factory [6] [17] [22] [61] [62].

The concentrations of metals (Cu, Fe, Cd, Pb, Zn, Cr and Ni) were compared to mean values in urban soils in the world (**Table 4**). The mean values of lead in the analyzed soil were much lower than those reported from different areas in the world. It is clear that the mean values of lead in the soil samples lower than those presented for soil samples from industrial areas presented in **Table 4**. The significantly high concentration of lead in soil samples was consistent with the results findings of Bi *et al.* [63], Al-Khashman and Shawabkeh [1], Wu *et al.* [64], and Ogunkunle and Fatoba [65]. Copper, Zinc and chromium in the investigated area were generally lower than those reported for other areas in the world (**Table 4**).

The higher values of metals in the study area were found closer to the industrial area, which clearly represents the source to be anthropogenic and not natural sources [58] [73] [74] [75]. Highly significant positive correlations between metals in all samples of soil such as Pb versus Zn, Cd, and Cu $R^2 = (0.852, 0.701$ and $0.713)$ respectively (**Table 5**). Iron is one of the principle metals in the Earth's crust and is mainly associated with other sources, its generally deposited in the neighborhood of the emission sources [61] [71] [76]. Higher values of iron were measured to the eastern side of the cement factory ($28.68 \text{ mg}\cdot\text{kg}^{-1}$ dry soil), but the lowest value of iron was found in the upper part of soil sample where the sample was collected around 50 m away from the entrance to the cement factory beside the parking site. However, the higher value of iron was also found in the nearby mechanical vehicle and traffic sites. A significantly positive correlation at $P < 0.01$ was found between metal pairs Fe-Mn (0.652), Fe-Cr (0.734) and Fe-Zn

Table 4. Comparison of mean concentrations (mg·kg⁻¹) of metals in urban soils in various sites around the world.

Location	Pb	Zn	Cd	Fe	Cu	Mn	Cr	References
Palermo	253.00	151.00	-	-	77.00	519.00	39.00	Manta <i>et al.</i> [5]
Hong Kong (China)	95.00	125.00	-	-	23.30	-	23.00	Li <i>et al.</i> [32]
Torino	149.00	183.00	-	-	90.00	-	191.00	Biasioli <i>et al.</i> [66]
Madrid	161.00	210.00	-	-	72.00	-	75.00	De Miguel <i>et al.</i> [67]
Aberdeen	94.40	58.50	-	-	27.00	-	23.90	Paterson <i>et al.</i> [68]
London	294.00	183.00	-	-	73.00	-	-	Thornton [69]
Nanjing, China	104.00	96.00	-	-	104.00	-	97.00	Lu <i>et al.</i> [70]
Central Jordan	62.17	146.94	4.98	-	-	-	83.93	Banat <i>et al.</i> [22]
South Jordan	55.00	44.51	5.00	24.18	2.89	-	22.18	Al-Khashman & Shawabkeh [1]
Queen Alia Airport, Jordan	60.20	51.43	6.55	47.82	3.02	-	17.32	Al-Khashman & Shawabkeh [71]
Ulaanbaatar	63.90	158.70	0.80	-	35.90	-	20.30	Batjargal <i>et al.</i> [2]
Changchun, China	35.40	90.00	0.13	-	29.40	-	66.00	Yang <i>et al.</i> [72]
Ghore, Jordan	49.77	48.81	3.33	65.30	28.65	46.62	14.08	Al-Khashman [73]
Ewekoro, Nigeria	0.24	5.98	-	440	0.54	8.56	0.66	Okoro <i>et al.</i> [41]
This study (0 - 10 cm)	47.92	48.81	3.36	14.81	4.01	37.65	13.20	Present study

Table 5. Correlation matrix between metals in urban samples; cells show the Pearson correlation coefficient and the corresponding P-value.

	Pb	Zn	Cd	Fe	Cu	Mn	Cr
Pb							
Zn	0.852 0.000						
Cd	0.701 0.002	0.401 0.002					
Fe	0.394 0.001	0.646 0.000	0.470 0.000				
Cu	0.713 0.001	0.588 0.001	0.701 0.000	0.556 0.001			
Mn	0.610 0.000	0.815 0.000	0.151 0.000	0.652 0.002	0.230 0.000		
Cr	0.235 0.000	0.613 0.001	0.484 0.001	0.734 0.000	0.518 0.000	0.233 0.000	

(0.646). The highest copper concentration was measured near the vegetation areas in the east and northwest of cement factory (Figure 2). This results shows that the source of soil contamination such as anthropogenic activities, agricultural soils receive metals mainly from fertilizers, pesticides, manure and other scattered diffuse pollution sources such as traffic emissions and incineration [61]

[66] [77]. The lowest value of copper was measured in the upper part of soil (10 - 20 cm) with a mean value of $1.67 \text{ mg}\cdot\text{kg}^{-1}$ dry soil. A good correlation was found between the metal pairs Cu-Cd (0.701), Cu-Pb (0.713) and moderate correlation between Cu-Zn (0.588) were shown in **Table 4**.

In general, cadmium was found to be lower in concentration compared to the other metals in soil. The mean concentration of cadmium in the upper part of soil was $3.36 \text{ mg}\cdot\text{kg}^{-1}$ dry soil, while in the lower part of soil mean value was $6.06 \text{ mg}\cdot\text{kg}^{-1}$ dry soil. A significantly good correlation was found between Cd and Cu pairs (0.701). Based on the result of metals values in soil, zinc concentration was the second highest value after the lead concentration. The mean value of zinc was analyzed to be $48.81 \text{ mg}\cdot\text{kg}^{-1}$ dry soil in the upper soil and $19.32 \text{ mg}\cdot\text{kg}^{-1}$ dry soil in the lower part of soil. An acceptable correlation between metals pairs Zn and Cd (0.401) and between Zn and Cr (0.613) were obtained. The highest concentration of zinc in soil sample may be derived from anthropogenic activities, whereas the abrasion of tires of motor vehicles may be considered as the second source of the traffic emissions [20] [58] [61] [75] [78] [79] [80]. The high value of zinc in soil samples were associated mainly with the emission sources of the cement industry and traffic emissions in the studied area. According to Ellis and Revitt [81], the Zn and Cd contamination of soils results from the mechanical abrasion of vehicle parts such as brake lining, oil leaked sumps and also associated with tire wear. Chromium and manganese values exhibit generally low values in the soil samples. The highest values of chromium were reported in the eastern side of the cement industry, but the lowest value of chromium was noticed in the reference soil samples (**Figure 3**). The highest value of manganese was measured in the south western part of the study area ($66.33 \text{ mg}\cdot\text{kg}^{-1}$ dry soil), while the lowest value was measured in the reference soil sample ($19.56 \text{ mg}\cdot\text{kg}^{-1}$ dry soil). The source of manganese in soil sample was interpreted to reflect a natural enrichment by weathering and natural processes and may be from automobile tires [82]. In general, the levels of metals in the topsoil in the study area were compared with the mean values of metals concentrations in the topsoil of other industrialized areas. The comparison results were presented in **Table 4**. It is clear that the mean values of lead in the analyzed soils are much lower than those reported for soil samples from industrial areas.

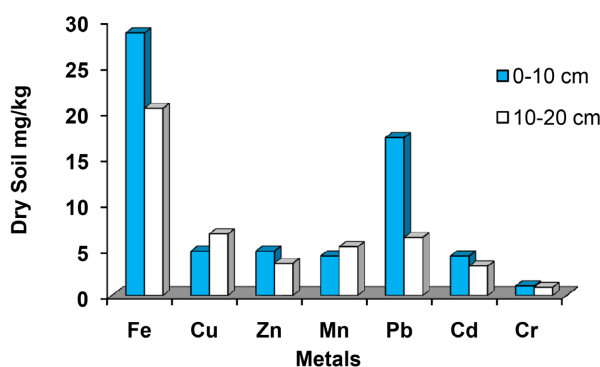


Figure 3. Mean value of metal concentrations in reference soil.

3.1.3. Statistical Analysis and Data Treatment

The understanding the relationship between metals and soil properties Pearson's correlation coefficients were used to measure the degree of correlation between logarithms of the metal data [1] [83] [84]. The relationship proved insight into the distribution and fate of heavy metals in soil. The relationship between soil properties and metals were presented in **Table 5**. A significant good correlation data (>0.65) was found between Pb and Zn, and Cu and Cr and Cr and Zn versus Mn and Cd versus Cu. These correlations suggest that the source of the metals is similar to that of the origin of metals in the soil sample was related to the industrial activities. Lead values showed very weak positive correlation with Fe and Cr. This can be explained by the minimal amount of Cr in the soil. In this study, no significant correlation between pH, TOM, CEC and CaCO₃ found and this can be explained to the narrow range of pH (6.33 - 8.16) measured in soil samples. This process has limited importance on the behavior, fate and mobility and distribution of metal in soils which it substantially limiting their mobility due to neutral sub-alkaline environment [73], and no relationship shows that the source of contamination might be differing from the other materials [4]. Principal Component Analysis (PCA) can be used to determine the source of contamination more accurately, which extracting the eigenvalues from the relationship matrix and provide information on the distribution and source of metal contamination. The results of statistical analysis of metals were displayed in **Table 6**.

Table 6. Factor loadings for varimax rotated PCA of metal data in soil samples (bold loadings are statistically).

Parameters	Factor 1	Factor 2	Factor 3
pH	-0.282	-0.536	0.930
EC	-0.223	0.461	0.765
TOM	0.320	-0.242	0.729
CaCO ₃	0.232	0.598	0.136
CEC	-0.153	0.206	0.751
Pb	0.714	0.413	-0.214
Zn	0.754	0.299	-0.147
Cd	0.745	0.176	0.235
Fe	0.220	0.722	-0.213
Cu	0.550	0.581	-0.154
Cr	0.220	0.577	-0.236
Mn	0.814	0.352	0.101
Eigenvalue	4.388	1.288	1.128
% variance	39.896	11.708	10.249
% cumulative	39.896	51.604	61.850

Factor 1 accounts for 39.89% of the total variance which is dominated by high loadings on the metals Pb, Zn and Cd indicates the influence of the anthropogenic activities on the properties of soil samples. The local industrial anthropogenic influences were further emphasizing by soil samples were collected beside the cement industry which it depending on the grainsize, grain particle of soil samples and prevailing wind direction [28] [71] [83]. Lead and zinc were significantly correlated as can be shown from their correlation coefficient, and have a common traffic and automobile sources, coupled with industrial sources [62] [80] [85] [86]. Al-Khashman [87] showed that Zn in dust results from the abrasion of vehicle parts such as brake linings, oil leak sumps wear and tear of vulcanized vehicle tires, and due to corrosion of galvanized automobile parts [28]. Factor 2, explained about 11.71% of the total variance and presents high loadings of Fe, Cr, Cu and soil characteristics CaCO_3 . This factor has high loadings of natural and anthropogenic sources [28] [34]. The third factor is accounts for 10.24% of the total variance. This factor was composed by the soil characteristics pH, EC, CEC and OM %. Based on the PCA, factor 1 represents the contribution of metals from local anthropogenic activities, but the factor 2 represented the contribution of metals from lithogenic and anthropogenic sources. Meanwhile, factor 3 represents the physicochemical parameters and has no significant. The results of statistical analysis and data treatment of the contamination of metals emphasizing that cement emissions and anthropogenic activities such as, agricultural activities and traffic emissions represent the major source of contamination in the study area. Hence, both the physical and chemical parameters of the shows a strong influence on the bioavailability of metals and should be considered in future remediation decision of a small scale of area. Meanwhile, understanding the relationship between soil characteristics and heavy metals distribution, fate and behavior provides good information into the assessment, monitoring and management of remediation actions to minimize the distribution of metals in the investigated area.

3.2. Metals Distribution in Street Dust

3.2.1. Physic-Chemical Parameters of Street Dust

The results of metals in street dust samples vary greatly according to the strength and direction of wind, pH and composition of dust fall. The pH values were in interval range 6.63 - 8.30, indicating weak acidic, neutral to sub-alkaline conditions of the dust samples. The higher values of pH in street dust samples were determined in the samples were collected in the residential area. The relatively higher pH value was referring to the high content of carbonaceous material in the investigated area [57] [72]. This explain that the changes of soil chemistry (acidity) can influence neutral compositions in the soils by removing the bivalent base (such as Ca^{2+} and Mg^{2+}) from the distribution in the study area [6] [88]. The values of electrical conductivity were in the range of 112 ± 2.42 to $770 \mu\text{s}/\text{cm} \pm 83.0$. The high electrical conductivity (EC) value ($770 \pm 83.0 \mu\text{s}/\text{cm}$) was found close to the cement factory with increasing values in the Qadissiya area, while

the lowest value of conductivity was found at the background site (112 ± 2.42 $\mu\text{s}/\text{cm}$) (Table 7). However, the higher electrical conductivity was estimated direct to the cement factory with propagation values in residential part. Total organic matter (TOM %) analyzed in dust samples were ranged from 3.4% to 5.6%. The highest values of organic matter were collected at the northwestern side of study area, which reflects the variable distribution of plants, palm trees, olive, fruits and vegetation in the study area. The CaCO_3 values were vary from 1.8 to 3.7 %. The result indicates that the dust samples in the industrial areas and the major streets were calcareous and carbonate content of dust collected from the major street in the investigated area. The higher value of CaCO_3 (3.7%) was higher than that reported previously (2.1% by Al-Khashman [87], and 1.2% by Al-Chalabi and Hawker [89]), but it is lowest than 3.9 % measured by Al-Khashman [6].

3.2.2. Distribution of Metals

The measured mean values of metals in the street dust samples were illustrated in Table 7. The highest level of metal was measured in the samples from street dust of the industrialized area except for cadmium and lead the highest value of which were found in the samples from street dust samples of the heavy traffic areas inside the cement factory as shown in Table 7 and Figure 4. However, the lowest value of metal ions was found in the samples were analyzed from street dust at the background (control). The mean metal concentration levels increased according to the following trend: $\text{CFe} > \text{CZn} > \text{CPb} > \text{CMn} > \text{CCu} > \text{CCd} > \text{CCr}$ where C stands for concentration.

Table 7. Mean and standard deviation of metals values in street dust samples ($\text{mg}\cdot\text{kg}^{-1}$), $N = 88$ samples.

Parameters	Sites				
	A	B	C	D	I
pH	7.85 ± 0.1	6.63 ± 1.2	7.77 ± 2.1	8.30 ± 2.9	7.9 ± 2.51
EC ($\mu\text{s}/\text{cm}$)	660 ± 96	566 ± 103	380 ± 102	330 ± 98	112 ± 2.4
OM %	4.7 ± 3.1	3.6 ± 6.1	4.4 ± 6.1	5.3 ± 2.1	3.6 ± 2.4
CaCO_3 %	3.6 ± 2.1	1.8 ± 1.4	3.7 ± 4.3	2.8 ± 3.1	2.8 ± 3.2
Fe	3460 ± 19.7	3256 ± 1.6	3017 ± 1.2	2891 ± 1	2011 ± 2
Zn	210 ± 6.7	190 ± 7.3	155 ± 3.6	$117 \pm 3.$	44 ± 1.8
Cu	20.7 ± 3.1	22.1 ± 1.4	18.6 ± 4.3	$20.6 \pm 2.$	12.8 ± 2.8
Pb	106 ± 3.9	88 ± 7.2	65 ± 3.4	36 ± 1.2	14.8 ± 2.4
Cr	11.0 ± 2.1	9.0 ± 2.1	10.0 ± 1.4	9.7 ± 0.9	2.8 ± 1.4
Cd	2.7 ± 3.8	2.41 ± 1.8	1.7 ± 4.1	1.3 ± 1.5	1.5 ± 2.4
Mn	98.0 ± 4.3	75.0 ± 3.6	66.7 ± 4.3	$59.1 \pm 4.$	66 ± 2.4

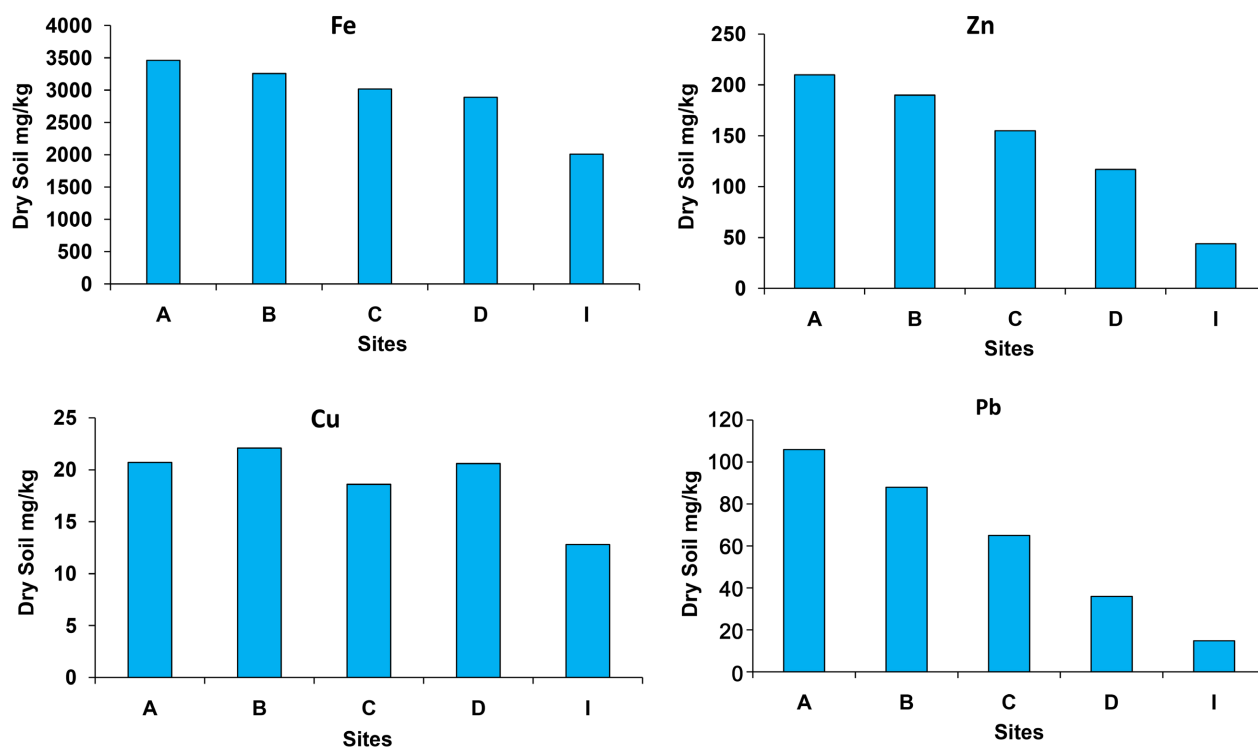


Figure 4. Mean concentrations of the metals in the street dust samples. A: High traffic, B: Moderate traffic, C: Light traffic, D: Residential streets, and I: Background sites.

According to the results of values at nine points, the highest lead level $106.0 \text{ mg}\cdot\text{kg}^{-1}$ dry soil in the street dust samples were collected in the high traffic area, but the lowest lead concentration $14.8 \text{ mg}\cdot\text{kg}^{-1}$ dry soil were found at the background area (control). The high content of lead was due to the industry cement process and production which requires essential amount of energy supplied by burning fossil fuel and large emission from automobiles, and vehicle emission. A significantly positive correlation was found between the metal pairs Pb-Zn (0.87) and Pb-Cu (0.75). The value of copper in the samples was found to be in the range of 26.4 to $12.8 \text{ mg}\cdot\text{kg}^{-1}$ dry soil. A good correlation was found between Cu-Pb (0.75), where the high value of Cu near the car services area may be derived from mechanical abrasion of vehicles and may be associated with the electrical devices in the study area. The highest value of Cu was found in the street dust samples from heavy traffic area [80] [87]. The concentration of zinc in the street dust samples were in the range 265 - $44 \text{ mg}\cdot\text{kg}^{-1}$ dry soil. The highest value of Zn was measured in the industrial sites from workplace of car service, but the lowest value was found at the background (control) area. According to Al-Khashman [20], the Cu and Zn contamination of roadside, soils result from the abrasion of vehicle parts such as oil leak sumps, cylinder head gaskets, tires of motor vehicle and brake linings. High correlation was found between the elemental pairs Zn-Cu (0.91) and Zn-Pb (0.88). The maximum concentration of iron was measured in the dust samples in the industrial sites ($6288 \text{ mg}\cdot\text{kg}^{-1}$ dry soil) and the minimum iron value was found in background sample ($2011 \text{ mg}\cdot\text{kg}^{-1}$ dry

soil). A positive correlation between Zn, Cu and Pb, supports the result that they are influenced by traffic emissions and anthropogenic activities were the main source of metals in the study area. Comparison of metal values in the street dust with those of various areas around the world was given in **Table 8**. The levels of Fe, Cu, Mn, Cd and Cr in street dust from study area were lowest among the compared sites. However, some of the metals in dust were found to be slightly higher than that found in the other sites.

3.2.3. Assessment of Contamination Level

1) Enrichment Factor (EF)

Enrichment factor (EF) is a convenient of geochemical trends it used for making comparison between different areas and it used to distinguish between natural or anthropogenic source of pollution and also determine the degree of metal contamination in the environment [92] [93]. Based on enrichment factor (EF), if EF value between 0.5 to 1.5 indicates the metal was originated from crustal materials or natural processes whereas EF greater than 1.5 suggest that the sources are more likely to be anthropogenic. The EF values can be divided into three contamination categories: Less enrichment (<10), intermediately enrichment ($10 < EF < 100$), and highly enrichment ($100 < EF$) [3] [6] [94].

The results of EF for this study are present in **Table 9**. The results show that the Zn and Mn have less enrichment with $EF < 1.5$ and indicating crustal natural influence such as weathering process. The highest mean EF for Zn, Pb, Cr and Cd were indicated in all sites with the value greater than 10 (medium enrichment). This suggests that metals, except Mn, were accumulated in street dust and street side soil primary from vehicular and industrial activities. The results indicate that the concentration of metals in soil samples was significantly affected by anthropogenic activities.

Table 8. Mean value of the metal values ($\text{mg}\cdot\text{kg}^{-1}$) in the street dust samples in various sites and industrial cities.

Site	Pb	Cu	Zn	Ni	Fe	Mn	Cd	Cr	References
Qadissiya	106	26.40	265	-	6255	102	2.70	14.7	Present work
Ma'an (Jordan)	105	26.42	260	134	6154	105	3.21	-	Al-Khashman [6]
Kavala (Greece)	301	124	272	58	-	-	0.20	-	Christoforidis and Stamatis [90]
Luanda (Angola)	266	38	98	10	-	258	1.10	-	Baptista and De Miquel [46]
Bahrain	697	-	152	126	-	-	72.00	-	Akhter and Madany [82]
Aviles	514	183	4829	-	42200	-	22.30	-	Ordonez <i>et al.</i> [91]
Amman (Jordan)	236	177	358	88	7132	-	1.70	-	Al-Khashman [47]
Warsaw	57	31	166	12	-	-	0.70	-	Manta <i>et al.</i> [5]
Jeddah, Saudi Arabia	97.36	80.90	245.45	25.83	7074.1	367.34	1.55	45	Khoder <i>et al.</i> [80]
Nigeria	61	56.50	72	1.23	69	1.15	1.54	2	Mafuyai <i>et al.</i> [55]

2) Principle Component Analysis (PCA)

Principle component analysis (PCA) can be used to distinguish the source of contaminants more accurately which extracting the eigenvalues from the variance [4] [6] [28] [34] [84] [95]. The results of statistical analysis were presented in **Table 10**. There are three eigenvalues higher than one and those three factors.

Factor one accounting for 39.895% of the total variance has high loadings for Fe and Mn which indicates the influence of natural and anthropogenic sources. However, this factor could be identified as resuspension of soil dust [96]. This factor was likely to be of natural crustal origin with traces of anthropogenic activities [34] [95]. On the other hand, factor two indicates that about 11.712% of the total variance which had high loadings on the elements Zn, Pb and Cu. These metals are related to motor vehicle emission, nonferrous metal smelting, and waste incineration [95] [96]. According to Thorpe and Harrison [97] and Al-Momani [98] the Pb derived from vehicular emission, brake abrasions and tyres contribute significant amount of Pb in dust samples. Faiz *et al.* [99] also found that Pb was strongly associated with emissions from fossil fuels and

Table 9. Enrichment factor (EF) of metals in street dust samples.

Sites	EF (Pb)	EF (Zn)	EF (Cr)	EF (Cd)	EF (Cu)	EF (Mn)
A	107.26	45.93	2.14	1.40	4.88	2.25
B	90.34	36.87	3.15	1.30	5.54	1.93
C	85.46	31.41	4.34	1.14	5.62	1.91
D	46.39	22.39	2.17	1.08	6.54	2.20
I	38.44	16.40	2.18	1.93	6.16	1.01
Mean	73.578	30.600	2.796	1.370	5.748	1.860

Table 10. Factor loadings for varimax rotated PCA of metal data in street dust samples.

Parameters	Factor 1	Factor 2	Factor 3
Pb	0.309	0.877	0.214
Zn	0.415	0.889	0.523
Cd	0.232	0.489	0.721
Fe	0.887	0.312	0.213
Cu	0.322	0.821	0.256
Cr	0.232	0.510	-0.216
Mn	0.814	0.352	0.101
Eigenvalue	4.378	1.277	1.128
% variance	39.895	11.712	10.249
% cumulative	39.897	51.614	61.855
Possible source	Soil dust	Vehicle emissions/Street erosion	Brake lining wear

industrial activities. The third factor which account for 10.249% of the total variance and presented in high loadings of Cd, and Zn. Al-Momani [98] found Pb to be strongly associated with vehicular emissions and Zn associated with various metal smelting and other industries. According to Fergusson and Kim [100], Mn, Cu, and Cd were associated with vehicles related source such as corrosion of metallic part, concrete materials, re-entrained dust from streets and tear and wear of tyres and engine parts. The results of the statistical analysis and distribution of the contamination of metals suggested that industrial activities and vehicle emissions represents the most important pollutant source for the studied area.

4. Conclusions

This study assessed the level of metal content and potential health risk of metals in the industrialized areas. The values of heavy metals in the topsoil and dust revealed that the samples had been enriched and contaminated with heavy metals such as Fe, Zn, Cu, Pb, Cr, Cd and Mn. These samples were examined by flame atomic absorption spectro-photometer to monitor, assess and to compare topsoil and road dust pollution levels of metals among the different types of urban environment. The mean values of metals determined decreased in the order $CZn > CPb > CMn > CFe > CCu > CCr > CCd$ where C is the concentration of these metals in solution. The highest values for these metals were found in the relation to industrial activities, traffic emissions and the operations of the cement factory. However, the lowest values of the metals were found in the reference soil.

The results of this study show that levels of metals in the street dust samples in investigated area are comparable to the other metal contents in urban dust levels worldwide. However, the values of Pb, Zn and Cd in urban soils are generally lower than those reported for some contaminated sites.

The result of analysis of the enrichment factor showed that most of the metals analyzed were enriched and enrichment comes from anthropogenic activities. It shows that these metals may increase over time if proactive or safety steps are not taken to monitor contamination sources in the investigated area. The maximum values for Cu, Cd, and Pb were measured in the industrial areas, due to the various metals processing industries such as electroplating and galvanizing, welding, and smelting. Meanwhile, the high value of Zn in the dust samples resulted from high traffic was attributed to the extensive use of galvanized-iron roofing, traffic emissions, tear of vulcanized rubber tyres and wear of brake lining materials.

Statistical analysis of the analyzed data of metals suggests that industrial activities together with the traffic emissions and agricultural activities are mainly responsible for metal pollution, as the highest metal values were found closely to the area utilization types and anthropogenic activities. Based on the results of this study, there are no significant variations in pH values between the soil sam-

ples. This can be attributed to buffering effect of carbonate material that are used as a raw material in the cement industry and from the major constituents of the emitted aerosols and dust related to atmospheric environment. This study recommends performing regular monitoring program in the future to evaluate and study of accumulating metals in soil and street dust quality to ensure effective management and protection of urban environment.

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Authors' Contributions

All authors contributed in collecting data, data analysis, interpretation of data and writing this article and approved the article. Omar Al-Khashman: collection of sampling, analysis of sampling, data curation, writing-original draft; final approval of the manuscript; Alia Al-Khashman: literature review and editing, software utilization; literature review; Hani Alnawafleh: writing-review and editing, and formatting the final manuscript; N. Rajesh Jesudoss Hynes: formal analysis, data curation, and final approval of the manuscript; N.P. Shenbaga, Velu: literature review, data interpretation and visualization.

Conflicts of Interest

On behalf of all authors, the corresponding author declares that there is no conflict of interest.

References

- [1] Al-Khashman, O.A. and Shawabkeh, R.A. (2006) Metals Distribution in Soils around the Cement Factory in Southern Jordan. *Environmental Pollution*, **140**, 387-394. <https://doi.org/10.1016/j.envpol.2005.08.023>
- [2] Batjargal, T., Otgonjargal, E., Baek, K. and Yang, J.S. (2010) Assessment of Metals Contamination of Soils in Ulaanbaatar, Mongolia. *Journal of Hazardous Materials*, **184**, 872-876. <https://doi.org/10.1016/j.jhazmat.2010.08.106>
- [3] Lu, X., Wang, L., Li, L., Lei, K., Huang, L. and Kang, D. (2010) Multivariate Statistical Analysis of Heavy Metals in Street Dust of Baoji, NW, China. *Journal of Hazardous Materials*, **173**, 744-749. <https://doi.org/10.1016/j.jhazmat.2009.09.001>
- [4] Duan, Z.B., Wang, J., Zhang, Y. and Xuan, B. (2017) Assessment of Heavy Metals Contamination in Road Dust from Different Functional Areas in Guiyang, Southwest, China. *International Journal of Environmental & Science Education*, **12**, 427-439.
- [5] Manta, D.S., Angelone, M., Bellanca, A., Neri, R. and Sprovieri, M. (2002) Heavy Metals in Urban Soils: A Case Study from the City of Palermo (Sicily), Italy. *The Science of the Total Environment*, **300**, 229-243. [https://doi.org/10.1016/S0048-9697\(02\)00273-5](https://doi.org/10.1016/S0048-9697(02)00273-5)
- [6] Al-Khashman, O.A. (2013) Assessment of Heavy Metals Contamination in Deposited Street Dusts in Different Urbanized Areas in the City of Ma'an, Jordan. *Envi-*

- ronmental Earth Science*, **70**, 2603-2612. <https://doi.org/10.1007/s12665-013-2310-6>
- [7] Kim, H.S., Kim, Y.J. and Seo, Y.R. (2015) An Overview of Carcinogenic Heavy Metal: Molecular Toxicity Mechanism and Prevention. *Journal of Cancer Prevention*, **20**, 232-240. <https://doi.org/10.15430/JCP.2015.20.4.232>
- [8] Alsbou, E.M. and Al-Khashman, O.A. (2018) Heavy Metal Concentrations in Roadside Soil and Street Dust from Petra Region, Jordan. *Environmental Monitoring Assessment*, **190**, Article No. 48. <https://doi.org/10.1007/s10661-017-6409-1>
- [9] Bayrakli, B. and Dengiz, O. (2019) Determination of Heavy Metal Risk and Their Enrichment Factor in Intensive Cultivated Soils of Tokat Province. *Eurasian Journal of Soil Science*, **8**, 249-256. <https://doi.org/10.18393/ejss.567357>
- [10] Waqar, A.J. and Riffat, N.M. (2019) Geochemical Approach for Heavy Metals in Sub-Urban Agricultural Soils of Sialkot, Pakistan. *SN Applied Sciences*, **1**, Article No. 161. <https://doi.org/10.1007/s42452-019-0167-3>
- [11] Ndiokwere, C.L. (1984) A Study of Heavy Metal Pollution from Motor Vehicle Emissions and Its Effect on Roadside Soil, Vegetation and Crop in Nigeria. *Environmental Pollution Series B, Chemical and Physical*, **7**, 35-42. [https://doi.org/10.1016/0143-148X\(84\)90035-1](https://doi.org/10.1016/0143-148X(84)90035-1)
- [12] Hewitt, C.N. and Candy, G.B.B. (1990) Soil and Street Dust Heavy Metal Concentrations in and around Cuenca, Ecuador. *Environmental Pollution*, **36**, 129-136. [https://doi.org/10.1016/0269-7491\(90\)90063-1](https://doi.org/10.1016/0269-7491(90)90063-1)
- [13] Olajire, A.A. and Ayodele, E.T. (1997) Contamination of Street Side Soil and Grass with Heavy Metals. *Environment International*, **23**, 91-101. [https://doi.org/10.1016/S0160-4120\(96\)00080-3](https://doi.org/10.1016/S0160-4120(96)00080-3)
- [14] Jaradat, Q. and Momani, K. (1999) Contamination of Roadside Soil, Plants and Air with Heavy Metals in Jordan, a Comparative Study. *Turkish Journal of Chemistry*, **23**, 209-220. <https://journals.tubitak.gov.tr/chem/vol23/iss2/13>
- [15] Dekimpe, C.R. and Morel, J.F. (2000) Urban Soil Management: A Growing Concern. *Soil Science*, **165**, 31-40. <https://doi.org/10.1097/00010694-200001000-00005>
- [16] Matos, A.T., Fontes, M.P.F., Costa, L.M. and Martinez, M.A. (2001) Mobility of Heavy Metals as Related to Soil Chemical and Mineralogical Characteristics of Brazilian Soils. *Environmental Pollution*, **111**, 429-435. [https://doi.org/10.1016/S0269-7491\(00\)00088-9](https://doi.org/10.1016/S0269-7491(00)00088-9)
- [17] Tüzen, M. (2003) Determination of Heavy Metals in Soil, Mushroom and Plant Samples by Atomic Absorption Spectrometry. *Micro Chemical Journal*, **74**, 289-297. [https://doi.org/10.1016/S0026-265X\(03\)00035-3](https://doi.org/10.1016/S0026-265X(03)00035-3)
- [18] Hu, C.W., Chao, M.R., Wu, K.Y., Chang-Chien, G.P., Lee, W.J., Chang, L.W. and Lee, W.S. (2003) Characterization of Multiple Airborne Particulate Metals in the Surroundings of a Municipal Waste Incinerator in Taiwan Region. *Atmospheric Environment*, **37**, 2845-2852. [https://doi.org/10.1016/S1352-2310\(03\)00208-5](https://doi.org/10.1016/S1352-2310(03)00208-5)
- [19] Charlesworth, S., Everett, M., McCarthy, R., Ordonez, A. and DeMiguel, E. (2003) A Comparative Study of Heavy Metal Concentration and Distribution in Deposited Street Dusts in a Large and a Small Urban Area: Birmingham and Coventry, West Midlands, UK. *Environmental International*, **29**, 563-573. [https://doi.org/10.1016/S0160-4120\(03\)00015-1](https://doi.org/10.1016/S0160-4120(03)00015-1)
- [20] 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**, 6803-6812. <https://doi.org/10.1016/j.atmosenv.2004.09.011>
- [21] Chen, T.B., Zheng, Y.M., Lei, M., Huang, Z.C., Wu, H.T., Chen, H., Fan, K.K., Yu,

- K., Wu, X. and Tian, Q.Z. (2005) Assessment of Heavy Metal Pollution in Surface Soils of Urban Parks in Bijing, China. *Chemosphere*, **60**, 542-551. <https://doi.org/10.1016/j.chemosphere.2004.12.072>
- [22] Banat, K.M., Howari, F.M. and Al-Hamad, A.A. (2005) Heavy Metals in Urban Soils of Central Jordan: Should We Worry about Their Environmental Risk. *Environmental Research*, **97**, 258-273. <https://doi.org/10.1016/j.envres.2004.07.002>
- [23] Zhang, C. (2006) Using Multivariate Analyses and GIS to Identify Pollutants and Their Spatial Patterns in Urban Soils in Galway, Ireland. *Environmental Pollution*, **142**, 501-511. <https://doi.org/10.1016/j.envpol.2005.10.028>
- [24] Chen, X., Xia, X., Zhao, Y. and Zhang, P. (2010) Heavy Metal Concentrations in Street Side Soils and Correlation with Urban Traffic in Beijing, China. *Journal of Hazardous Materials*, **181**, 640-646. <https://doi.org/10.1016/j.jhazmat.2010.05.060>
- [25] Li, X. and Feng, L. (2012) Multivariate and Geostatistical Analyses of Metals in Urban Soil of Weinan Industrial Areas, Northwest of China. *Atmospheric Environment*, **47**, 58-65. <https://doi.org/10.1016/j.atmosenv.2011.11.041>
- [26] Du, Y., Gao, B., Zhou, H., Ju, X., Hao, H. and Yin, S. (2013) Health Risk Assessment of Heavy Metals in Road Dusts in Urban Parks of Beijing, China. *Procedia Environmental Sciences*, **18**, 299-309. <https://doi.org/10.1016/j.proenv.2013.04.039>
- [27] Adesuyi, A.A., Njoku, K.L. and Akinola, M.O. (2015) Assessment of Heavy Metals Pollution in Soils and Vegetation around Selected Industries in Lagos State, Nigeria. *Journal of Geoscience and Environment Protection*, **3**, 11-19. <https://doi.org/10.4236/gep.2015.37002>
- [28] Naderizadeh, Z., Khademi, H. and Ayoubi, S. (2016) Biomonitoring of Atmospheric Heavy Metals Pollution Using Dust Deposited on Date Palm Leaves in Southwestern Iran. *Atmosfera*, **29**, 141-155. <https://doi.org/10.20937/ATM.2016.29.02.04>
- [29] Han, X., Lu, X., Tu, Q. and Wu, Y. (2017) Health Risks and Contamination Levels of Heavy Metals in Dusts from Parks and Squares of an Industrial City in Semi-Arid Area of China. *International Journal of Environmental Research and Public Health*, **14**, Article 886. <https://doi.org/10.3390/ijerph14080886>
- [30] Zhang, Z.Y., Yang, X.D. and Yang, S.T. (2018) Heavy Metal Pollution Assessment, Source Identification, and Health Risk Evaluation in Aibi Lake of Northwest China. *Environmental Monitoring and Assessment*, **190**, Article No. 69. <https://doi.org/10.1007/s10661-017-6437-x>
- [31] Cai, K. and Li, C. (2019) Street Dust Heavy Metal Pollution Source Apportionment and Sustainable Management in a Typical City, Shijiazhuang, China. *International Journal of Environmental Research and Public Health*, **16**, Article 2625. <https://doi.org/10.3390/ijerph16142625>
- [32] Li, X., Poon, C. and Liu, P.S. (2001) Heavy Metal Contamination of Urban Soils and Street Dusts in Hong Kong (China). *Applied Geochemistry*, **16**, 1361-1368. [https://doi.org/10.1016/s0883-2927\(01\)00045-2](https://doi.org/10.1016/s0883-2927(01)00045-2)
- [33] Bilos, C., Colombo, J.C., Skorupka, C.N. and Rodriguez Presa, M.J. (2001) Sources, Distribution and Variability of Airborne Trace Metals in La Plata City Area, Argentina. *Environmental Pollution*, **111**, 149-158. [https://doi.org/10.1016/s0269-7491\(99\)00328-0](https://doi.org/10.1016/s0269-7491(99)00328-0)
- [34] Möller, A., Müller, H.W., Abdullah, A., Abdelgawad, G. and Utermann, J. (2005) Urban Soil Pollution in Damascus, Syria: Concentrations and Patterns of Heavy Metals in the Soils of the Damascus Ghouta. *Geoderma*, **124**, 63-71. <https://doi.org/10.1016/j.geoderma.2004.04.003>
- [35] Wei, B., Jiang, F., Li, X. and Mu, S. (2009) Spatial Distribution and Contamination

- Assessment of Heavy Metals in Urban Road Dusts From Urumqi, NW China. *Microchemical Journal*, **93**, 147-152. <https://doi.org/10.1016/j.microc.2009.06.001>
- [36] Ahmed, F. and Ishiga, H. (2006) Trace Metal Concentrations in Street Dusts of Dhaka City, Bangladesh. *Atmospheric Environment*, **40**, 3835-3844. <https://doi.org/10.1016/j.atmosenv.2006.03.004>
- [37] Nriagu, J.O. (1989) A Global Assessment of Natural Sources of Atmospheric Trace Metals. *Nature*, **338**, 47-49. <https://doi.org/10.1038/338047a0>
- [38] Bermudez, G.M.A., Moreno, M., Invernizzi, R., Plá, R. and Pignata, M.L. (2010) Heavy Metal Pollution in Topsoils Near a Cement Plant: The Role of Organic Matter and Distance to the Source to Predict Total and HCl-extracted Heavy Metal Concentrations. *Chemosphere*, **78**, 375-381. <https://doi.org/10.1016/j.chemosphere.2009.11.012>
- [39] Aribigbola, A., Fatusin, A. and Adejomo, F. (2012) Assessment of Health and Environmental Challenges of Cement Factory on Ewekoro Community Residents, Ogun State. *American Journal of Human Ecology*, **1**, 51-57.
- [40] Mandal, A. and Voutchkov, M. (2011) Heavy Metals in Soils around the Cement Factory in Rockfort, Kingston, Jamaica. *International Journal of Geosciences*, **2**, 48-54. <https://doi.org/10.4236/ijg.2011.21005>
- [41] Okoro, H.K., Orimolade, B.O., Adebayo, G.B., Akande, B.A., Ximba, B.J. and Ngila, J.C. (2017) An Assessment of Heavy Metals Contents in the Soil around a Cement Factory in Ewekoro, Nigeria Using Pollution Indices. *Polish Journal of Environmental Studies*, **26**, 221-228. <https://doi.org/10.15244/pjoes/62389>
- [42] Department of Meteorology (2016) Internal Report Data and Files of the Department of Meteorology.
- [43] Bender, F. (1974) *Geology of Jordan: Supplementary Edition in English with Minor Revision*. Gebruder Borntraeger, Berlin.
- [44] Powell, J.H. (1988) *The Geology of the Karak Area*. Geological Mapping Division Bull 8, Geology Division. Natural Resources Authority, Amman.
- [45] Bäckröm, M., Karlsson, S. and Allard, B. (2004) Metal Leachability and Anthropogenic Signal in Roadside Soils Estimated from Sequential Extraction and Stable Lead Isotopes. *Environmental Monitoring Assessment*, **90**, 135-160. <https://doi.org/10.1023/B:EMAS.0000003572.40515.31>
- [46] Baptista, L.F. and De Migue, L.E. (2005) Geochemistry and Risk Assessment of Street Dust in Luanda, Angola: A Tropical Urban Environment. *Atmospheric Environment*, **39**, 4501-4512. <https://doi.org/10.1016/j.atmosenv.2005.03.026>
- [47] Al-Khashman, O.A. (2007) The Investigation of Metal Concentrations in Street Dust Samples in Aqaba City, Jordan. *Environmental Geochemistry and Health*, **29**, 197-207. <https://doi.org/10.1007/s10653-006-9065-x>
- [48] Mason, B.J. (1966) *Introduction to Geochemistry*. 3rd Edition, John Wiley, New York.
- [49] Madrid, L., Barrientos, E.D. and Madrid, F. (2002) Distribution of Heavy Metal Contents of Urban Soils in Parks of Seville. *Chemosphere*, **49**, 1301-1308. [https://doi.org/10.1016/S0045-6535\(02\)00530-1](https://doi.org/10.1016/S0045-6535(02)00530-1)
- [50] Hesse, P.R. (1972) *Textbook of Soil Chemical Analysis*. Chemical Publishing Company, New York.
- [51] Page, A.L., Miller, R.H. and Keeney, D.R. (1982) *Methods of Soil Analysis. Part 2: Chemical and Mineralogical Properties*. American Society of Agronomy. <https://doi.org/10.2134/agronmonogr9.2.2ed>

- [52] Biswas, T.D. and Mukherjee, S.K. (1988) Soil Science Textbook. McGraw-Hill, New Delhi.
- [53] Banerjee, A.D.K. (2003) Heavy Metal Levels and Solid Phase Speciation in Street Dusts of Delhi, India. *Environmental Pollution*, **123**, 95-105. [https://doi.org/10.1016/s0269-7491\(02\)00337-8](https://doi.org/10.1016/s0269-7491(02)00337-8).
- [54] Lu, S.G. and Bai, S.Q. (2009) Contamination and Potential Mobility Assessment of Heavy Metals in Urban Soils of Hangzhou, China: Relationship with Different Land Uses. *Environmental Earth Sciences*, **60**, 1481-1490. <https://doi.org/10.1007/s12665-009-0283-2>
- [55] Mafuyai, G.M., Kamoh, N.M., Kangpe, N.S., Ayuba, S.M. and Eneji, I.S. (2015) Heavy Metals Contamination in Roadside Dust along Major Traffic Roads in Jos Metroplition Area, Nigeria. *Journal of Environment and Earth Science*, **5**, 48-57. <https://api.semanticscholar.org/corpusid:43977768>
- [56] Haynes, B.W. and Kramer, G.W. (1992) Characterization of U.S Cements Kiln Dust U.S. Bureau of Mines, Department of Interior. Information Circular No. 8885.
- [57] Ge, Y., Murray, P. and Hendershot, W.H. (2000) Trace Metal Speciation and Bioavailability in Urban Soils. *Environmental Pollution*, **107**, 137-144. [https://doi.org/10.1016/s0269-7491\(99\)00119-0](https://doi.org/10.1016/s0269-7491(99)00119-0)
- [58] Khamparia, A., Chattergee, S.K. and Sharma, G.D. (2012) Assessment on Effect of Cement Dust Pollution on Soil Health. *Journal of Environmental Research and Development*, **7**, 368-374. <https://api.semanticscholar.org/corpusid:54698820>
- [59] Wufem, B.M., Ibrahim, A.Q., Maina, H.M., Gunsat, N.J. and Barnabas, N.J. (2014) Quality Evaluation and Physico-Chemical Properties of Soils around a Cement Factory in Gombe State, Nigeria. *International Conference on Advances in Agricultural, Biological & Environmental Sciences (AABES2014)*, Dubai, 15-16 October 2014, 42-45.
- [60] Balasubramanian, V., Singh, L., Nnadi, L.A. and Mokwunye, A.U. (1984) Fertility Status of Some Upland Savanna Soils of Nigeria Under Fallow and Cultivation. *Samaru Journal of Agricultural Research*, **2**, 13-23.
- [61] Carreras, H.A. and Pignata, M.L. (2002) Biomonitoring of Heavy Metals and Air Quality in Cordoba City, Argentina, Using Transplanted Lichens. *Environmental Pollution*, **117**, 77-87. [https://doi.org/10.1016/s0269-7491\(01\)00164-6](https://doi.org/10.1016/s0269-7491(01)00164-6)
- [62] Han, Y.M., Du, P.X., Cao, J.J. AND Posmentier, E.S. (2006) Multivariate Analysis of Heavy Metal Contamination in Urban Dusts of Xi'an, Central China. *Science of the Total Environment*, **355**, 176-186. <https://doi.org/10.1016/j.scitotenv.2005.02.026>
- [63] Bi, X., Feng, X., Yang, Y., Qiu, G., Li, G., Li, F., Liu, T., Fu, Z. and Jin, Z. (2006) Environmental Contamination of Heavy Metals From Zinc Smelting Areas in Hezhang County, Western Guizhou, China. *Environment International*, **32**, 883-890. <https://doi.org/10.1016/j.envint.2006.05.010>
- [64] Wu, Y., Xu, Y., Zhang, J. and Hu, S. (2010) Evaluation of Ecological Risk and Primary Empirical Research on Heavy Metals in Polluted Soil Over Xiaoqinling Gold Mining Region, Shaanxi, China. *Transactions of Nonferrous Metals Society of China*, **20**, 688-694. [https://doi.org/10.1016/s1003-6326\(09\)60199-0](https://doi.org/10.1016/s1003-6326(09)60199-0)
- [65] Ogunkunle, C.O. and Fatoba, P.O. (2014) Contamination and Spatial Distribution of Heavy Metals in Topsoil Surrounding a Mega Cement Factory. *Atmospheric Pollution Research*, **5**, 270-282. <https://doi.org/10.5094/apr.2014.033>
- [66] Biasioli, M., Barberis, R. and Ajmonemarsan, F. (2006) The Influence of a Large City on Some Soil Properties and Metals Content. *Science of the Total Environment*, **356**, 154-164. <https://doi.org/10.1016/j.scitotenv.2005.04.033>

- [67] De Miguel, E., Jiménez de Grado, M., Llamas, J.F., Martín-Dorado, A. and Mazadi-ego, L.F. (1998) The Overlooked Contribution of Compost Application to the Trace Element Load in the Urban Soil of Madrid (Spain). *Science of the Total Environ-ment*, **215**, 113-122. [https://doi.org/10.1016/s0048-9697\(98\)00112-0](https://doi.org/10.1016/s0048-9697(98)00112-0)
- [68] Paterson, E., Sanka, M. and Clark, L. (1996) Urban Soils as Pollutant Sinks—A Case Study from Aberdeen, Scotland. *Applied Geochemistry*, **11**, 129-131. [https://doi.org/10.1016/0883-2927\(95\)00081-x](https://doi.org/10.1016/0883-2927(95)00081-x)
- [69] Thornton, I. (1991) Metal Contamination of Soils in Urban Area. In: Bullok, P. and Gregory, P.J., Eds., *Soil in the Urban Environment*, Blackwell, London, 47-75. <https://doi.org/10.1002/9781444310603.ch4>
- [70] Lu, Y., Gong, Z., Zhang, G. and Burghardt, W. (2003) Concentrations and Chemical Speciations of Cu, Zn, Pb and Cr of Urban Soils in Nanjing, China. *Geoderma*, **115**, 101-111. [https://doi.org/10.1016/s0016-7061\(03\)00079-x](https://doi.org/10.1016/s0016-7061(03)00079-x)
- [71] Al-Khashman, O.A. and Shawabkeh, R.A. (2009) Metal Distribution in Urban Soil around Steel Industry beside Queen Alia Airport, Jordan. *Environmental Geo-chemistry and Health*, **31**, 717-726. <https://doi.org/10.1007/s10653-009-9250-9>
- [72] Yang, Z., Lu, W., Long, Y., Bao, X. and Yang, Q. (2011) Assessment of Heavy Metals Contamination in Urban Topsoil from Changchun City, China. *Journal of Geo-chemical Exploration*, **108**, 27-38. <https://doi.org/10.1016/j.gexplo.2010.09.006>
- [73] Al-Khashman, O.A. (2012) Assessment of Heavy Metal Accumulation in Urban Soil around Potash Industrial Site in the East of the Dead Sea and Their Environmental Risks. *Soil and Sediment Contamination: An International Journal*, **21**, 276-290. <https://doi.org/10.1080/15320383.2011.609358>
- [74] Olowoyo, J.O. (2015) Trace Metals in Soil and Plants around a Cement Factory in Pretoria, South Africa. *Polish Journal of Environmental Studies*, **24**, 2087-2093. <https://doi.org/10.15244/pjoes/43497>
- [75] Solgi, E. and Khodabandelo, H. (2016) Cadmium and Lead Disruption in Soils around the Hegmatan Cement Factory, Iran. *Health Scope*, **5**, e34184. <https://doi.org/10.17795/jhealthscope-34184>
- [76] Berg, T., Røyset, O., Steinnes, E. and Vadset, M. (1995) Atmospheric Trace Element Deposition: Principal Component Analysis of ICP-MS Data from Moss Samples. *Environmental Pollution*, **88**, 67-77. [https://doi.org/10.1016/0269-7491\(95\)91049-q](https://doi.org/10.1016/0269-7491(95)91049-q)
- [77] Wong, M.H., Chen, T.B. and Wong, J.W.C. (1996) Trace Metal Contamination of the Hong Kong (China) Soil Environment: A Review. In: Naidu, R., Kookana, R.S., Oliver, D.P., Rogers, S. and McLaughlin, M.J., Eds., *Contaminants and the Soil Environment in the Australia-Pacific Region*, Klumer Academic Publisher, Dordrecht, 501-511. https://doi.org/10.1007/978-94-009-1626-5_16
- [78] Beckwith, P.R., Ellis, J.B. and Revitt, D.M. (1985) Particle Size Distribution of Cu, Pb and Zn across a Road Surface. *International Conference Heavy Metals in the Environment*, Athens, September 1985, 174-176.
- [79] Garty, J., Kauppi, M. and Kauppi, A. (1996) Accumulation of Airborne Elements from Vehicles in Transplanted Lichens in Urban Sites. *Journal of Environmental Quality*, **25**, 265-272. <https://doi.org/10.2134/jeq1996.00472425002500020009x>
- [80] Mansour, A. and Al Ghamdi, M.A.A.G. (2012) Heavy Metal Distribution in Street Dust of Urban and Industrial Areas in Jeddah, Saudi Arabia. *Journal of King Abdulaziz University—Meteorology, Environment and Arid Land Agriculture Sciences*, **23**, 55-75. <https://doi.org/10.4197/met.23-2.4>
- [81] Bryan Ellis, J. and Revitt, D.M. (1982) Incidence of Heavy Metals in Street Surface Sediments: Solubility and Grain Size Studies. *Water, Air, and Soil Pollution*, **17**,

- 87-100. <https://doi.org/10.1007/bf00164094>
- [82] Salim Akhter, M. and Madany, I.M. (1993) Heavy Metals in Street and House Dust in Bahrain. *Water, Air, & Soil Pollution*, **66**, 111-119. <https://doi.org/10.1007/bf00477063>
- [83] Garcia, R. and Millán, E. (1998) Assessment of Cd, Pb and Zn Contamination in Roadside Soils and Grasses from Gipuzkoa (Spain). *Chemosphere*, **37**, 1615-1625. [https://doi.org/10.1016/s0045-6535\(98\)00152-0](https://doi.org/10.1016/s0045-6535(98)00152-0)
- [84] Ebqa'ai, M. and Ibrahim, B. (2017) Application of Multivariate Statistical Analysis in the Pollution and Health Risk of Traffic-Related Heavy Metals. *Environmental Geochemistry and Health*, **39**, 1441-1456. <https://doi.org/10.1007/s10653-017-9930-9>
- [85] Day, J.P., Hart, M. and Robinson, M.S. (1975) Lead in Urban Street Dust. *Nature*, **253**, 343-345. <https://doi.org/10.1038/253343a0>
- [86] Al-Omran, A.M., El-Maghraby, S.E., Nadeem, M.E.A., El-Eter, A.M. and Al-Qahtani, S.M. (2011) Impact of Cement Dust on Some Soil Properties around the Cement Factory in Al-Hasa Oasis, Saudi Arabia. *American-Eurasian Journal of Agricultural & Environmental Sciences*, **11**, 840-846. [https://idosi.org/aejaes/jaes11\(6\)11/12.pdf](https://idosi.org/aejaes/jaes11(6)11/12.pdf)
- [87] Al-Khashman, O.A. (2007) Determination of Metal Accumulation in Deposited Street Dusts in Amman, Jordan. *Environmental Geochemistry and Health*, **29**, 1-10. <https://doi.org/10.1007/s10653-006-9067-8>
- [88] Sinex, S.A. and Helz, G.R. (1981) Regional Geochemistry of Trace Elements in Chesapeake Bay Sediments. *Environmental Geology*, **3**, 315-323. <https://doi.org/10.1007/bf02473521>
- [89] Al-Chalabi, A. (1997) Response of Vehicular Lead to the Presence of Street Dust in the Atmospheric Environment of Major Roads. *Science of the Total Environment*, **206**, 195-202. [https://doi.org/10.1016/s0048-9697\(97\)00224-6](https://doi.org/10.1016/s0048-9697(97)00224-6)
- [90] Christoforidis, A. and Stamatis, N. (2009) Heavy Metal Contamination in Street Dust and Roadside Soil along the Major National Road in Kavala's Region, Greece. *Geoderma*, **151**, 257-263. <https://doi.org/10.1016/j.geoderma.2009.04.016>
- [91] Ordóñez, A., Loredó, J., De Miguel, E. and Charlesworth, S. (2003) Distribution of Heavy Metals in the Street Dusts and Soils of an Industrial City in Northern Spain. *Archives of Environmental Contamination and Toxicology*, **44**, 160-170. <https://doi.org/10.1007/s00244-002-2005-6>
- [92] Sinex, S.A. and Helz, G.R. (1981) Regional Geochemistry of Trace Elements in Chesapeake Bay Sediments. *Environmental Geology*, **3**, 315-323. <https://doi.org/10.1007/bf02473521>
- [93] Kanu, M.O., Meludu, O.C. and Oniku, S.A. (2015) Evaluation of Heavy Metal Contents in Road Dust of Jalingo, Taraba State, Nigeria. *Jordan Journal of Earth and Environmental Sciences*, **7**, 65-70. https://jjees.hu.edu.jo/files/vol7n1/vol7n1_hq_p65-70.pdf
- [94] Lu, X., Wang, L., Lei, K., Huang, J. and Zhai, Y. (2009) Contamination Assessment of Copper, Lead, Zinc, Manganese and Nickel in Street Dust of Baoji, NW China. *Journal of Hazardous Materials*, **161**, 1058-1062. <https://doi.org/10.1016/j.jhazmat.2008.04.052>
- [95] Atiemo, M.S., Ofosu, G.F., Mensah, H.K., Tutu, A.O., Palm, L. and Blankson, S.A. (2011) Contamination Assessment of Heavy Metals in Road Dust from Selected Roads in Accra, Ghana. *Research Journal of Environmental and Earth Sciences*, **3**, 473-480. <https://maxwellsci.com/print/rjees/v3-473-480.pdf>

- [96] Arditoglou, A. and Samara, C. (2005) Levels of Total Suspended Particulate Matter and Major Trace Elements in Kosovo: A Source Identification and Apportionment Study. *Chemosphere*, **59**, 669-678. <https://doi.org/10.1016/j.chemosphere.2004.10.056>
- [97] Thorpe, A. and Harrison, R.M. (2008) Sources and Properties of Non-Exhaust Particulate Matter from Road Traffic: A Review. *Science of the Total Environment*, **400**, 270-282. <https://doi.org/10.1016/j.scitotenv.2008.06.007>
- [98] Al-Momani, I.F. (2009) Assessment of Trace Metal Distribution and Contamination in Surface Soils of Amman. Jordan. *Jordan Journal of Chemistry*, **4**, 77-87. <https://jjc.yu.edu.jo/index.php/jjc/article/view/441>
- [99] Faiz, Y., Tufail, M., Javed, M.T., Chaudhry, M.M. and Naila-Siddique, (2009) Road Dust Pollution of Cd, Cu, Ni, Pb and Zn along Islamabad Expressway, Pakistan. *Microchemical Journal*, **92**, 186-192. <https://doi.org/10.1016/j.microc.2009.03.009>
- [100] Fergusson, J.E. and Kim, N.D. (1991) Trace Elements in Street and House Dusts: Sources and Speciation. *Science of the Total Environment*, **100**, 125-150. [https://doi.org/10.1016/0048-9697\(91\)90376-p](https://doi.org/10.1016/0048-9697(91)90376-p)