Baghdad Science Journal

Volume 23 | Issue 5 Article 5

5-20-2026

Ecological Health Risk Assessment of Some Heavy Metals in Dust from Some Nursery and Primary Schools of Al-Kut City, Iraq

Wisam Thamer Al-Mayah
Department of Soil and Water Resources, College of Agriculture, University of Wasit, Wasit, Iraq, walmayah@uowasit.edu.iq

Zahraa Zahraw Al-Janabi
Environmental Research Center, University of Technology-Iraq, Baghdad, Iraq, zahraa.z.farhan@uotechnology.edu.iq

Isam Hani Hameed
Department of Soil and Water Resources, College of Agriculture, University of Wasit, Wasit, Iraq, ishani@uowasit.edu.iq

Follow this and additional works at: https://bsj.uobaghdad.edu.iq/home

How to Cite this Article

Al-Mayah, Wisam Thamer; Al-Janabi, Zahraa Zahraw; and Hameed, Isam Hani (2026) "Ecological Health Risk Assessment of Some Heavy Metals in Dust from Some Nursery and Primary Schools of Al-Kut City, Iraq," *Baghdad Science Journal*: Vol. 23: Iss. 5, Article 5.
DOI: https://doi.org/10.21123/2411-7986.5289

This Article is brought to you for free and open access by Baghdad Science Journal. It has been accepted for inclusion in Baghdad Science Journal by an authorized editor of Baghdad Science Journal. For more information, please contact mina.t@csw.uobaghdad.edu.iq.

BAGHDAD SCIENCE JOURNAL 2026;23(5):1592–1606

Scan the QR to view the full-text article on the journal website

RESEARCH ARTICLE

Ecological Health Risk Assessment of Some Heavy Metals in Dust from Some Nursery and Primary Schools of Al-Kut City, Iraq

Wisam Thamer Al-Mayah [1], **Zahraa Zahraw Al-Janabi** [2,*], **Isam Hani Hameed** [1]

[1] Department of Soil and Water Resources, College of Agriculture, University of Wasit, Wasit, Iraq
[2] Environmental Research Center, University of Technology-Iraq, Baghdad, Iraq

ABSTRACT

Heavy metals in dust are considered one of the most important environmental consequences of human activities. The objectives of this study are to investigate the ecological risk of heavy metals on human health in the dust of schools in Kut City, Iraq. The dust samples were collected from 25 primary schools and kindergartens. The pH, EC, TDS, and concentrations of heavy metals (Pb, Ni, Cr, Cd, Zn, Co, Mn) were measured. The heavy metals were analyzed using an atomic absorption spectrophotometer. The contamination factor (CF), enrichment factor (EF), and pollution load index (PLI) were calculated. The results showed that the mean concentration of Pb, Ni, Cr, Cd, Zn, Co, and Mn in the schools' dust were 37, 45, 60, 0.15, 73, 24, and 110 mg/kg, respectively. The mean concentration of all heavy metals was higher than the background concentration values of these metals, except for Mn and Ni. The highest amounts of Pb, Ni, and Cr were observed in schools 13, 7, and 1. The amounts of Cd were also significantly higher in schools 13, 7, and 23 than in other schools. The significant correlation between heavy metals shows that these metals have the same origin. The CF of most heavy metals was mainly in moderately contaminated ($1 \leq CF < 3$). The EF for most elements was mainly in the class of significant enrichment ($5 \leq EF < 20$). The PLI values ranged from 1.29 to 2.36, and 100% of the sampling fell into the polluted class.

Keywords: Dust contamination, Heavy metal, PCA, Pearson's correlation, Primary schools, Soil pollution indices

Introduction

Dust is an important component of atmospheric particles that fall to the ground due to gravity.[1] By studying dust, it is possible to identify particulate pollution indirectly.[2] One of the main reasons for studying dust is the inhalation of these particles by people because this dust is contaminated with heavy metals and endangers the health of people exposed to these pollutants.[3,4] There are many reports that dust endangers human health, especially for children, due to their lower tolerance to toxicity and involuntary ingestion of soil through the mouth.[5,6] Therefore, dust is known as an important source of pollution.[7] Dust originates from both natural and anthropogenic sources. Natural sources are produced by the weathering of rocks, soil erosion, volcanic ash, and sea salt.[8] Anthropogenic sources are produced by brake and tire wear, exhaust emissions,[9] and particulate matter emitted by industries.[10]

Depending on their origin and path, dust particles have a high ability to carry heavy metals.[11] The composition of dust is complex and variable, and the concentration of heavy metals in it varies greatly.[12] Heavy metals are one of the most dangerous groups of man-made pollutants due to their toxicity and

Received 8 August 2025; revised 11 October 2025; accepted 24 Novemebr 2025.
Available online 20 May 2026

* Corresponding author.
E-mail addresses: walmayah@uowasit.edu.iq (W. T. Al-Mayah), Zahraa.Z.Farhan@uotechnology.edu.iq (Z. Z. Al-Janabi), ishani@uowasit.edu.iq (I. H. Hameed).

https://doi.org/10.21123/2411-7986.5289
2411-7986/© 2026 The Author(s). Published by College of Science for Women, University of Baghdad. This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

persistence, and are of importance due to their non-degradability and physiological effects on humans and other organisms at low concentrations.[13] The study of heavy metal concentrations in dust is very important due to its impact on human health.[14] There are various natural and artificial sources of heavy metals in the environment.[15] These metals are mostly anthropogenic,[16] for example, burning fossil fuels, gases emitted from motor vehicles, machinery,[17] and heavy traffic increase the concentration of copper and lead.[18] The contamination factor (CF),[19] enrichment factor (EF),[20] pollution load index (PLI),[21] and geo-accumulation index (Igeo) are used to determine the levels of heavy metal contamination in dust.[22]

Today, many studies have been conducted on the concentration and dispersion of heavy metals in industrial areas in different countries. Radhi *et al.*[23] reported that industrial activity is the most important reason for the increase in the concentration of heavy metals in the atmospheric fallout of this city by studying the dust of Ramadi city.[23] Al-Heetya *et al.*[24] studied the street dust of Baghdad and showed that the concentration of heavy metals such as zinc, lead, nickel, and copper were higher than the concentrations of these metals in the earth's crust, and that these metals are produced as a result of vehicle fuel and wear of vehicle brake pads. The findings of Sezgin *et al.*[25] in Turkey on the concentration of heavy metals in street dust showed that the concentration of heavy metals in dust is several times higher than their concentration in soil. For example, the concentration of zinc is 9 to 12 times and lead is 9 to 11 times higher than the concentration of these elements in soil.[25]

Kut is one of the cities in Iraq that is currently facing a severe air pollution problem. In recent years, some studies have been conducted on air pollution in this city.[26,27] However, not many studies have been conducted on the investigation of pollution and ecological risk of heavy metals in dust fallout. Therefore, the present study aimed to determine the level of pollution and assess the ecological risk of heavy metals, including Cd, Cr, Cu, Ni, and Pb, in the dust of Kut city at the studied stations and to prepare a map of heavy metal distribution. Heavy metals are an important component of urban environmental pollution. To create a safer and healthier environment for the current population, having comprehensive information about dust can help us manage sustainable development and create a safer environment for residents. The major objectives of this study were to determine the levels of heavy metal concentration in dust samples collected from nursery and primary schools in Kut city and to assess the ecological risk of heavy metals in the region.

Materials and methods

Site description

The study was conducted in Al-Kut city, which is located in the Wasit province of Iraq, 160 km south of Baghdad City.[28] The longitude and latitude of the region are 32°31'N and 45°49'E. The city extends along the Tigris River and is the largest city in Wasit, as shown in Fig. 1.[29] The city of Al-Kut, the centre of Wasit Governorate in Iraq, is a typical example of an Iraqi city facing complex urban, environmental, and transport challenges. The city is located on both banks of the Tigris River, giving it a strategic location, but also causing many of its problems. In terms of area, the city has experienced random and unorganised urban expansion, especially after 2003, with construction encroaching on fertile agricultural land, which has had a negative impact on the environment and sustainable development. As for population density, it is unevenly distributed, with high densities concentrated on the outskirts (such as the Karama and Jihad neighbourhoods) despite the low economic level, while medium densities are concentrated in the centre and the northern and southern areas. This inefficient distribution leads to long and irregular daily commutes for residents.[29]

Sampling

Dust samples were collected from July to August 2024 from 20 primary schools, and 5 nursery schools in Kut city. 3-5 samples were collected randomly from the classroom floor, desks, Playgrounds, and windowsills and were mixed to form one composite sample. The dust was collected using a plastic brush and a pan and reserved in plastic bags. The collected samples were transferred to the Soil Laboratory in the Department of Soil and Water Resources/ College of Agriculture / University of Wasit. The samples were dried at 104 °C for two days and then sieved using a stainless-steel sieve of 106 μm diameter. The dust samples were then homogenized with a porcelain pestle and mortar. For the preparation of the sample for measuring heavy metals such as lead (Pb), nickel (Ni), chromium (Cr), cadmium (Cd), zinc (Zn), cobalt (Co), and manganese (Mn), the dust is held in a polyethylene vessel arranged for assimilation and examination. Closed container microwave-assisted acid assimilation method under high temperature and pressure has been developed, which evades the exogenic pollution and entails a shorter period of time and smaller amounts of acids, thus promoting the limits of detection and total accuracy of the testing technique. 0.5 grams of the dust

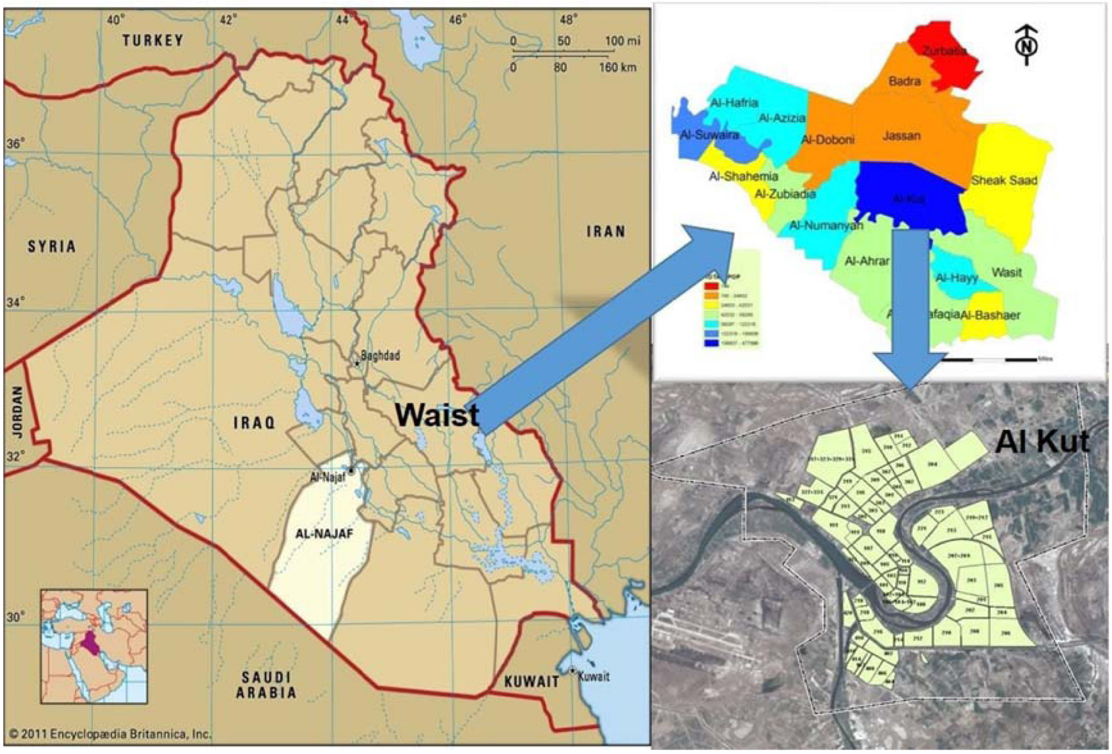

Fig. 1. The school sites selected for dust sampling in Kut city.

sample were put into the reference vessel. Twenty-five milliliters of mixture (HCl: H_2SO_4: HNO_3, 3:2:1) was then added to the reaction container, which was introduced into the microwave unit. After digestion, the solution was cooled and filtered. The filtrated sample was then diluted to 50 mL with deionized water and kept in specific vessels. An atomic absorption spectrophotometric instrument (Phoenix - 986, USA) was used to measure the heavy metal level in the dust samples, and the AAS operating conditions are mentioned in Table 1. Other chemical properties were measured in the dust samples, as pH was measured using a pH-meter (pH was calibrated with 4,7, and standard buffer solutions), electrical conductivity was measured by an EC-meter, and total dissolved solids were measured using a TDS-meter (WTW multi-parameter). 10 grams of dried dust sample were dissolved in a 100 mL conical flask, and then deionized water (50 mL) was added to the flask to get w/s ratio = 5 v/m. The flasks were laid horizontally in a shaker, and the dust-water mixture was shaken for 1 h at 160 oscillations/min at room temperature, then the parameters were measured in the supernatant. All samples of dust were prepared and analyzed according to Cabrera *et al.* [30] and USEPA. [31]

Quality control and assurance

Precision and bias were determined by analysis using reagent blanks and sample duplicates (Three replications for each sample were taken, and to get more accurate and precise results, each replicate was measured twice). All plastic and glassware used in the field and lab were soaked in 2% HNO_3 (for heavy metals analyses), and 10 % HCl (for other parameters) overnight, subsequently cleaned with detergent, thoroughly rinsed successively with tap water, followed by distilled water, and then dried in an oven at 37°C. By the proper selection of standards and instrument conditions, AAS calibration curves remained accurate.

Contamination assessment methods

Contamination factor (CF)

The contamination factor provides a description of heavy metal pollution in dust or soil. The contamination factor is obtained by dividing the heavy metal concentration in the collected sample by the concentration of the same metal in the background sample. The contamination factor was calculated as shown in Eq. (1):

$$CF = MX/Mb \quad (1)$$

Mx is the concentration of the heavy metal in the sample, and Mb is the concentration of the same metal in the reference or background sample Table 1. Gradations of CF are presented in four classes: low contamination factor (CF $\leq$ 1), medium contamination factor (3 $\leq$ CF$\leq$1), significant contamination

Table 1. Atomic absorption spectrophotometric instrument operating conditions.

Item	Specification
Wavelength	190-900 nm.
Wavelength Accuracy	0.25 nm.
Wavelength Repeatability	0.15 nm.
Monochromator	Czerny-Turner configuration.
Flame sensitivity	0.03μ/ ml/ 1 %.
Temperature range	Ambient-2650.
Deuterium Lamp background Correction	Abs.
Light source	8 hollow cathode lamps.
Analytical method	Flame, Graphite furnace, and hydride.
Repetitions	1 – 20 with calculations of average and SD.
Output	Output of parameters, final data, spectra and calibration curves.

factor ($6 \leq$ CF≤ 3), and very high contamination factor (CF$\geq$6).[32]

Enrichment factor (EF)

The enrichment factor for each metal was calculated from the ratio between the normalized element and the background value of the elements, according to the following equation. The reference element in determining the enrichment factor is an element that has a completely geological origin.

According to Chen *et al.*,[33] the EF is divided into five classes: deficiency to minimal enrichment (EF$\leq$ 2), moderate enrichment ($2 <$ EF ≤ 5), significant enrichment ($5 <$ EF ≤ 20), very high enrichment ($20 <$ EF ≤ 40) and extremely high enrichment (EF > 40). The enrichment factor calculation, as illustrated in Eq. (2):

$$EF = \frac{\left(\frac{Cx}{Cref}\right) sample}{\left(\frac{Cx}{Cref}\right) background} \quad (2)$$

(CX) sample is the element concentration in the sample, (Cx), background is the reference element concentration, (Cref), sample is the concentration of the reference element in the sample, (Cref) background is the concentration of the reference element in the background.

Pollution Load Index (PLI)

To check the toxicity of heavy metals in dust, the pollution load index was calculated according to Eq. (3):

$$PLI = \sqrt[n]{CF_{n1} \times \; CF_{n2} \times CF_{n3} \times \ldots\ldots.. \times CF_n} \quad (3)$$

Cf is the pollution factor of each heavy metal studied, and n is the number of metals to be measured. This index is divided into two groups as non-polluted dust (PLI$<$1) and polluted (PLI$>$1).[34]

Statistical analysis

All data were analyzed and graphed using OriginLab software (version 0.95.0). The comparison of the means was done using the LSD test at the probability level of one and five percent. EXCEL software was used to calculate pollution indicators.

Results and discussion

Data analysis

The descriptive statistics of the results data of the parameters of heavy metal, pH, EC, and TDS, including minimum, maximum, mean, and standard deviation, are presented in Table 2. The values showed that the distribution of data related to heavy metals in the dust samples of schools in Al-Kut city is as follows: Manganese > Zinc > Chromium > Nickel > Lead > Cobalt > Cadmium

The average concentration of Pb, Ni, Cr, Cd, Zn, Co, and Mn were 37, 45, 60, 0.15, 73, 24, and 110 mg/kg, respectively. The average concentration of all heavy metals is higher than the background concentration values of these metals, except for Mn and Ni.

Chemical characteristics of the school's dust

The results obtained showed that the lowest pH value was 5.32 in Rehab Al-Salihat School (S17), while the highest pH value was 8.07 in Al-Ghad Al-Saeed School (S8), as shown in Table 1 and Fig. 2. The statistical analysis showed that there were no significant differences ($P > 0.05$) between the pH values in the dust of the 25 studied schools.

Fig. 2 shows that the results that the lowest EC value, 2.63 dSm^{-1}, with TDS of 1.40 mg/l was recorded at Al-Ghad AlSaeed School (S8), while the highest value, 78.70 dSm^{-1}, with TDS of 50.33 mg/l was recorded at Al-Saror School (S2). Comparing the

Table 2. Descriptive statistics results of heavy metal values and chemical characteristics of school dust samples in Kut city; data represented as Min., Max., and Mean concentration ± S.D. value.

ID	Name of School (S)	Site Description	pH	EC dSm^{-1}	TDS mg/l	Pb mg/kg	Ni mg/kg	Cr mg/kg	Cd mg/kg	Zn mg/kg	Co mg/kg	Mn mg/kg
S1	Al-Ateaf School	Near a large garden	7.57	2.67	1.73	45	57	73	0.563	82	27	77
S2	Al-Saror School	Residential area	6.73	78.70	50.33	27	52	63	0.118	67	22	119
S3	Dar Alsalam school	Residential area	7.33	24.03	15.30	24	39	62	0.179	70	29	116
S4	Al-Bairaq School	Residential area	6.90	66.67	42.60	27	55	67	0.236	72	26	87
S5	Abdullah bin jaafar S.	Near a garden	7.37	16.37	10.43	30	47	61	0.136	68	19	43
S6	Al-Nathal School	Residential area	7.17	35.50	21.20	28	57	65	0.195	83	18	128
S7	Al-Duha School	Residential area	7.90	5.50	3.47	74	69	86	0.892	87	17	91
S8	Al-Ghad AlSaeed S.	Village	8.07	2.63	1.40	37	42	50	0.137	74	29	112
S9	Al-Ahrar School	Residential area	7.70	17.27	11.00	30	39	47	0.153	71	19	127
S10	Al-Nabaa School	Near an oil company	7.47	13.90	8.87	37	45	54	0.117	67	19	82
S11	Ard AlHussin School	Residential area	7.07	58.40	37.33	22	46	48	0.083	64	21	136
S12	Al-Khaleda School	Residential area	7.50	16.90	10.77	39	57	47	0.517	75	26	97
S13	Al-Nahoth School	Residential area	7.10	46.80	29.87	97	79	107	0.952	88	17	78
S14	Al-Nsejam School	Near an oil company	7.67	37.17	23.77	33	43	66	0.316	82	21	102
S15	Al-Hussainiya School	Near traffic	7.73	13.77	8.77	40	41	61	0.51	57	24	113
S16	Al-Fatimit School	Near traffic	7.53	13.30	8.43	27	30	37	0.153	61	27	103
S17	Rehab Al-Salihat S.	Residential area	5.32	11.90	7.57	43	48	58	0.123	83	30	136
S18	Ataa Al-Kawther S.	Near an oil company	7.60	29.03	18.57	45	44	54	0.47	77	25	128
S19	Mohsen Khanfas S.	Near a street	7.93	9.10	4.20	22	33	45	0.146	73	28	110
S20	Athab matrod School	Near a street	7.97	11.20	7.10	49	52	54	0.43	80	17	92
S21	Al-Moman School	Residential area	6.93	35.70	22.80	39	39	56	0.173	83	24	132
S22	Al-Tafaol School	Village	6.47	45.43	29.00	36	40	61	0.19	67	18	140
S23	Al-Farahidi School	Near a street	7.03	20.37	13.03	40	50	61	0.646	72	24	116
S24	Al-Taleaa School	Village	6.77	48.10	30.77	39	44	60	0.453	88	28	93
S25	Ibrahim AlKhalil S.	Near a street	7.07	5.23	3.30	45	40	55	0.253	73	25	102
Mean			7.37	17.27	11.00	37.00	45.00	60.00	0.195	73.00	24.00	110.00
Std.Dev.			±0.58	±20.47	±13.15	±15.98	±10.58	±13.67	±0.240	±8.36	±4.22	±22.58
Min.			5.32	2.63	1.40	22	30	37	0.083	57	17	43
Max.			8.07	78.70	50.33	97	79	107	0.952	88	30	140
Background						14	80	100	0.3	75	20	900

average values of EC and TDS in the dust of the 25 studied schools indicated the existence of a significant difference ($P > 0.05$) between the values of these parameters in some schools. The lowest values of EC and TDS were observed in the dust of schools 1, 8, and 25.

Heavy metals in school dust

The results of the Pb data analysis are presented in Table 1. As can be seen in this table, there is a significant difference ($P > 0.05$) between the amounts of lead in the dust of the 25 studied schools. Comparing the average values of lead in the dust of the 25 studied schools. Fig. 3 shows the presence of a significant difference ($P > 0.05$) between the values of lead in some schools. The highest amount of lead in dust was observed in schools 13, 7, and 20, respectively. Among all the schools, the lowest amount of lead was observed in the dust of schools No. 11 and 19.

The results of the Ni data analysis, as shown in Table 1, also indicate the existence of a significant difference ($P > 0.05$) between the dust nickel values of the 25 studied schools. Comparing the average nickel

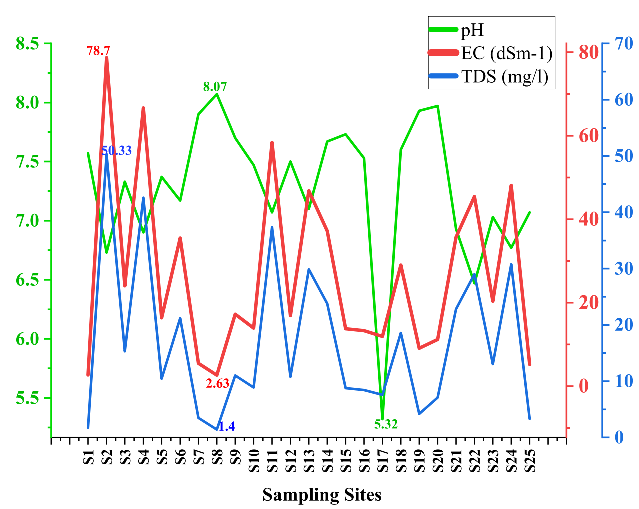

Fig. 2. Spatial variation of concentration of pH, EC, and TDS in the study area.

values in the 25 schools showed that the highest nickel values were in the dust of schools 13, 7, and 1. Among all the schools, the lowest amount of nickel was observed in the dust of school No. 16, as shown in Fig. 4.

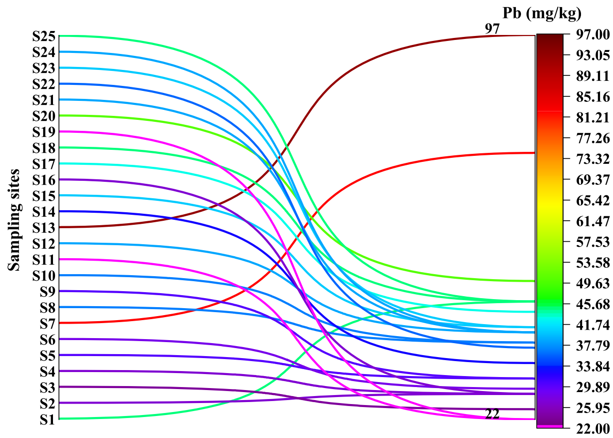

Fig. 3. Spatial distribution of concentration of Pb in the study area.

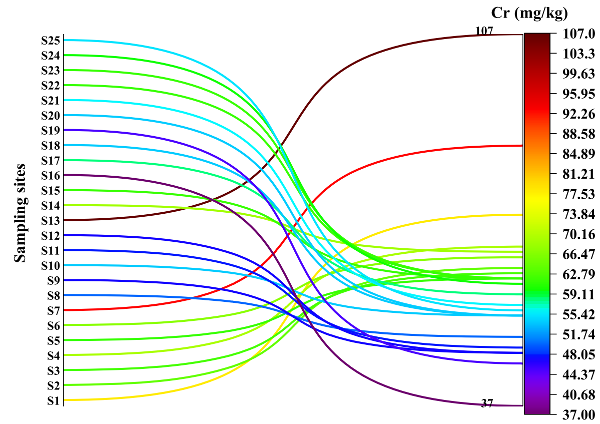

Fig. 5. Spatial distribution of concentration of Cr in the study area.

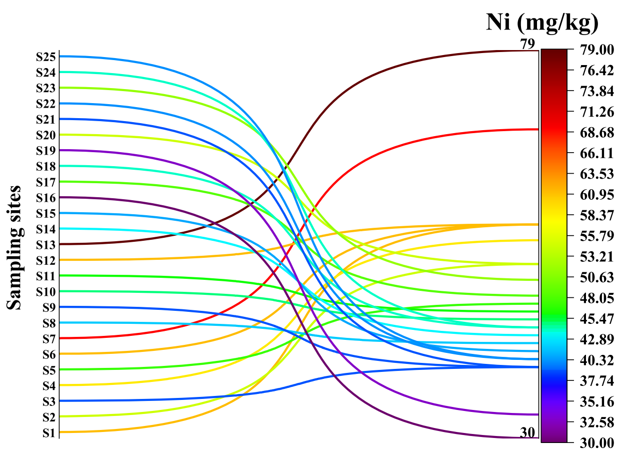

Fig. 4. Spatial distribution of the concentration of Ni in the study area.

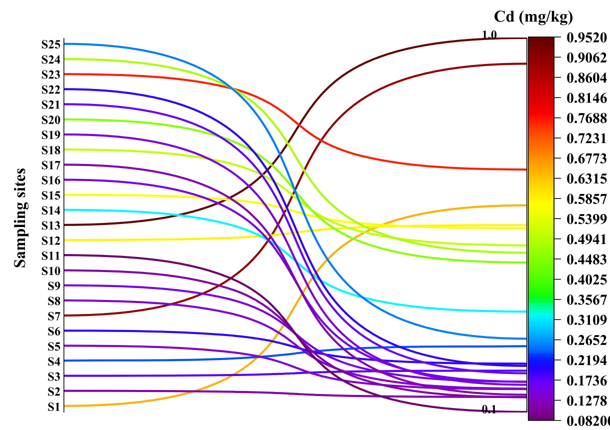

Fig. 6. Spatial distribution of concentration of Cd in study area.

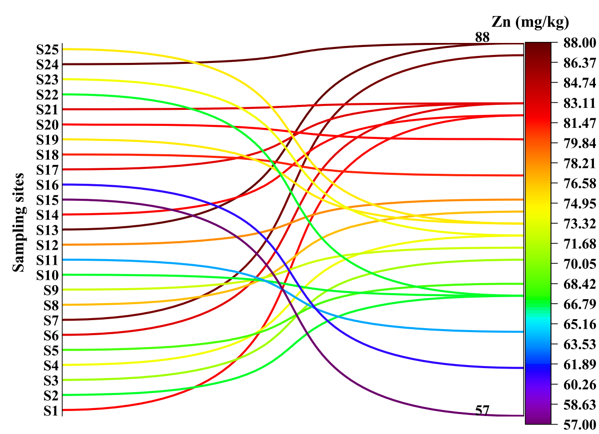

Fig. 7. Spatial distribution of the concentration of Zn in the study area.

The results of the Cr data analysis also indicate the existence of a significant difference ($P > 0.05$) between the dust chromium values of the 25 studied schools. Comparing the average chromium values in the 25 schools showed that the highest chromium values were in the dust of school number 13. Among all the schools, the lowest amount of chromium was observed in the dust of school No. 16, as shown in Fig. 5 and Table 1.

The results of the variance analysis of Cd indicated the existence of a significant difference ($P > 0.05$) between the amounts of cadmium in the dust of the study schools as given in Table 1 and Fig. 6 shows the comparison of the average values of cadmium in the 25 studied schools. Among these schools, Cd levels were significantly higher ($P > 0.05$) in schools 13, 7, and 23 than in other schools. Zn results were higher ($P > 0.05$) in schools 24, 13, and 7 Fig. 7.

The results of the variance analysis of Co, as illustrated in Table 1, indicate the existence of a significant difference ($P > 0.05$) between the amounts of cobalt in the dust of different schools. The comparison of the average values of Co in different schools showed that the trend of Co concentration changes in the dust of different schools is similar to the trend of Ni concentration changes in these schools, as illustrated in Fig. 8.

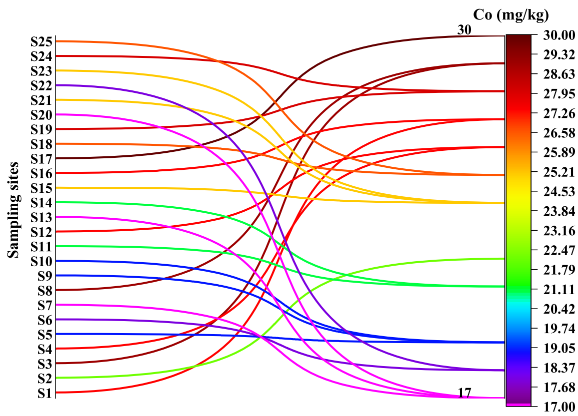

Fig. 8. Spatial distribution of concentration of Co in study area.

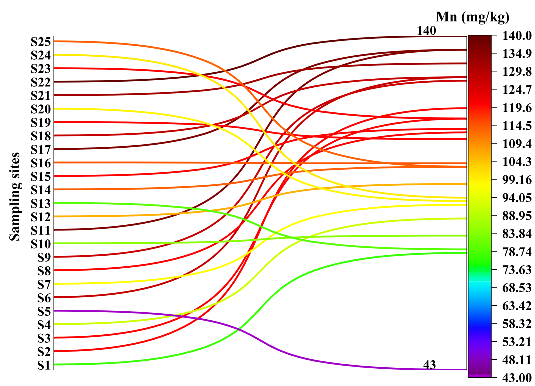

Fig. 9. Spatial distribution of concentration of Mn in the study area.

The results of the variance analysis of the Mn element are presented in Table 1. The concentration of this element, like the concentration of the previous elements in different schools, shows a significant difference ($P > 0.05$). A comparison of the average values of Mn concentration in the 25 schools is presented in Fig. 9. The highest concentration of Mn is observed in schools 6, 11, 17 and 22.

The results of Pearson's correlation matrix analysis between heavy metals in school dust in Kut city, as listed in Table 3, shows that most of the heavy metals have a significant correlation ($P > 0.05$) with each other. Only the correlation between Zn and Co and Mn is not significant. The presence of a significant correlation between heavy metals shows that these metals have the same origin. The positive and significant correlation between Ni, Pb, Cd, and Zn indicates the same origin of the release of these heavy metals in the environment.

The principal component analysis approach was used to determine the sources of heavy metals, and it was found that mixed sources, both natural and anthropogenic, may be responsible for the presence of heavy metals in the dust. The PCA was performed on seven heavy metal concentrations: Pb, Ni, Cr, Cd, Zn, Co, and Mn. The loadings for the first principal component (PC1) show that Ni (0.906), Pb (0.906), Cr (0.901), and Cd (0.860) have high positive loadings, indicating a strong positive correlation with PC1. Zn also has a positive loading (0.654) but falls in moderate positive loading (< 0.75), while Co (-0.461) and Mn (-0.452) have low negative loadings as given in Table 4.

These metals Ni, Pb, Cr, Cd, and Zn, remain major contributors to PC1, presenting high positive loadings along with their close proximity from the loadings plot as displayed in Fig. 10. This indicates that these heavy metals tend to change in unison or differ from a certain common source or environmental process, which the first principal component may represent. He *et al.*[35] reported that the heavy metals with high correlation coefficients in the environment could have similar sources, migration processes, and chemical behavior. Zeng *et al.*[36] applied the PCA-Geodetector and positive matrix factorization (PMF) technique to determine the source of heavy metals in soil and dust samples and found that PCA is better at identifying the pollution source and pointed to an increase in heavy metals in dust related directly to industrial activity.

The plot shows clearly that along the PC1 axis, the positive group (Pb, Ni, Cr, Cd, and, Zn) and the negative group of Co, Mn show an inverse relationship since they stand opposite each other from the origin; this indicates that if the concentrations of one group are high, those of the other tend to be low, or different underlying factors affect them.

In this study, Pb, Ni, Cr, and Cd, characterized by a high positive loading (> 0.75) according to,[28] where these groups can be influenced by the same source of pollution; these metals mainly originated from human activities or natural causes, where the climate in the area is influenced by multiple dust storms, especially during the summer.[37] That could be things like ongoing renovations inside buildings, use of specific products such as paint and electronics in schools or inhaling exhaust fumes from vehicles by open windows (Murat). It is worth remembering that these are old school buildings. While the group with high negative loading could be the result of mixed sources.[38] In terms of transportation and roads, the city suffers from a lack of a road hierarchy (motorways, arterial roads, local roads) and poor connections between its different parts, especially between the two banks, due to a lack of adequate bridges. This has led to heavy reliance on private vehicles, traffic congestion, frequent accidents, and a weak and inefficient public transport system.[30]

In general, populated cities suffer from environmental pollutants, with research indicating high concentrations of dangerous heavy metals such as

Table 3. The results of Pearson's correlation matrix between heavy metal concentrations in of schools dust samples in Kut city.

	Pb	Ni	Cr	Cd	Zn	Co	Mn
Pb	1						
Ni	0.738**	1					
Cr	0.770**	0.816**	1				
Cd	0.794**	0.617**	0.781**	1			
Zn	0.557**	0.540**	0.524**	0.432**	1		
Co	-0.317**	-0.407**	-0.374**	-0.273*	-0.070	1	
Mn	-0.297**	-0.370**	-0.344**	-0.310**	-0.118	0.158	1

*Marked correlations are significant.

Table 4. Component loadings matrix.

	PC1	Uniqueness
Ni	0.906	0.179
Pb	0.906	0.180
Cr	0.901	0.188
Cd	0.860	0.260
Zn	0.654	0.572
Co	-0.461	0.788
Mn	-0.452	0.796

Note. Applied rotation method is promax.

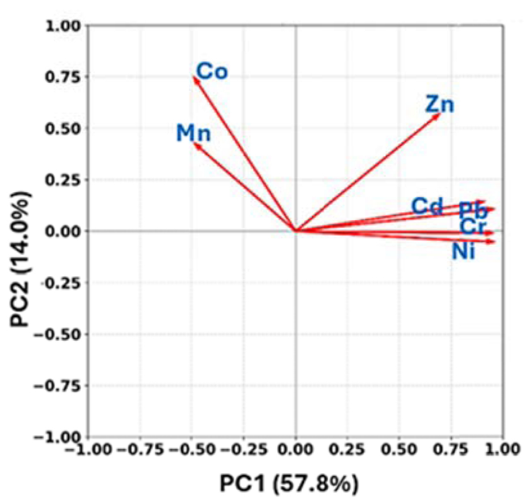

Fig. 10. PCA plot for heavy metals concentration under the study.

lead and cadmium in indoor dust, mainly from vehicle exhaust, tire friction and industrial activities. This problem is exacerbated by the presence of light industries within residential neighbourhoods and poor ventilation systems in buildings, which allow contaminated dust to enter from outside.[39]

Pollution indices

Contamination factor (CF)

The contamination factor (CF) was used to determine the degree of dust contamination with heavy metals. The heavy metal contamination factor of the heavy metals in the dust of the 25 study schools in Kut city is presented in Table 5.

The highest contamination factor of Pb is in schools 13 (CF=4.41), 7 (CF=3.35), and 1 (CF=2.06), which are significantly higher than other schools.

The highest Zn contamination factor is found in schools 13 (CF=1.54), 7 (CF=1.52), and 24 (CF=1.51), which are significantly higher than other schools. The contamination factor of Mn in school No. 1 (CF=0.85) is significantly higher than in other schools. In other schools, CF values ranged from 0.01-0.15.

The highest Ni contamination factor is found in schools 13 (CF=2.63), 7 (CF=2.29), and 24 (CF=1.91), which are significantly higher than other schools. The highest Cr contamination factor is also found in schools 13 (CF=2.86), 7 (CF=2.29), and 24 (CF=1.96), which is significantly higher than in other schools. The highest contamination of Cd is in school No. 13 (CF=3.173), 7 (CF=2.973), and 23 (CF=2.153), which is significantly higher than other schools; however, in other schools, the Cd contamination factor is high and close to these values.

On the other hand, school No. 13 had the highest mean CF for all the heavy metals except Co and Mn. The calculated mean CF values for trace elements increase in order: Mn < Cd < Zn < Co < Ni < Cr < Pb; with the values of 0.121, 0.65, 1.27, 1.42, 1.5, 1.6, and 1.67, respectively. Based on the pollution severity classification Table 1, school dust samples in Kut city show a low amount ($CF < 1$) of Mn (in all schools), while Pb, Ni, Cr, Cd, Co and Zn are moderately contaminated ($1 \leq CF < 3$) in all schools, except Pb in school No. 7 & 13, and Cd in school No.13 are classified as considerably contaminated ($3 \leq CF \leq 6$).

In general, the results of the CF showed that 100% of the Zn samples, 100% of the Ni samples, 100% of the Co samples, 100% of the Cr samples, 60% of the Pb samples, and 88% of the Cd samples were in the medium pollution class. Also, 12% of the Cd samples were in the very high pollution class, and 40% of the Pb samples were in the very high pollution class. It

Table 5. The statistical results of contamination factor (CF) of heavy metals in 25 schools' dust samples in Kut citynt at P < 0.05.

	CF values						
School (S)	Pb	Ni	Cr	Cd	Zn	Co	Mn
S1	2.06	1.91	1.96	1.876	1.43	1.6	0.155
S2	1.22	1.73	1.68	0.393	1.16	1.34	0.132
S3	1.1	1.29	1.63	0.596	1.22	1.72	0.128
S4	1.23	1.82	1.79	0.786	1.24	1.56	0.096
S5	1.35	1.56	1.62	0.453	1.17	1.12	0.047
S6	1.27	1.9	1.73	0.65	1.45	1.06	0.0141
S7	3.35	2.29	2.3	2.973	1.51	1	0.101
S8	1.66	1.4	1.35	0.456	1.29	1.76	0.124
S9	1.34	1.31	1.26	0.51	1.23	1.12	0.14
S10	1.67	1.5	1.43	0.39	1.16	1.12	0.091
S11	1	1.51	1.28	0.276	1.12	1.26	0.15
S12	1.78	1.9	1.26	1.723	1.3	1.58	0.108
S13	4.41	2.63	2.86	3.173	1.54	1.04	0.087
S14	1.5	1.47	1.77	1.05	1.43	1.24	0.113
S15	1.83	1.37	1.64	1.7	1	1.44	0.125
S16	1.24	1	1	0.51	1.06	1.64	0.114
S17	1.96	1.58	1.55	0.41	1.44	1.82	0.151
S18	2.05	1.47	1.45	1.567	1.34	1.52	0.141
S19	1	1.1	1.19	0.486	1.26	1.68	0.121
S20	2.22	1.74	1.44	1.433	1.39	1.04	0.101
S21	1.75	1.3	1.5	0.576	1.44	1.42	0.146
S22	1.64	1.33	1.62	0.633	1.16	1.06	0.85
S23	1.83	1.66	1.62	2.153	1.25	1.42	0.129
S24	1.75	1.45	1.60	1.51	1.52	1.68	0.103
S25	2.06	1.32	1.47	0.843	1.27	1.52	0.112
Mean	1.67	1.5	1.6	0.65	1.27	1.42	0.121
Std.Dev.	±0.726	±0.352	±0.365	0.798	±0.146	±0.260	±0.148
Min.	1	1	1	0.276	1	1	0.0141
Max.	4.41	2.63	2.86	3.173	1.54	1.82	0.85

can be said that, based on the contamination factor, the level of Zn, Ni, Co, and Cr pollution in the dust of the study area was medium, and the level of Cd and Pb pollution in the study area was medium to very high. This result indicates that vehicle traffic and wear of mechanical parts caused dust pollution in the study area.

Enrichment factor (EF)

The Enrichment Factor (EF) refers to the assessment of the level of pollution due to anthropogenic influence and its impact on soils and sediments,[40] the value of this factor determines the extent of pollution by heavy elements (Pb, Ni, Cr, Cd, Zn, Co and Mn) resulting from human activities (anthropogenic sources) and those from natural origin.[41] Accordingly, an enrichment index close to 1 indicates the natural origin of heavy metals. Values of 1 to 10 of this index are due to the influence of both natural and human sources, and an enrichment index above 10 indicates the origin of human factors (anthropogenic) heavy metals in dust.[42] Accordingly, in this study, Ni, Cd, and Cr metals present in the dust of schools in Kut city have natural and human origins, while Pb, Zn, and Co present in the dust of the study area have human origins because they have average values greater than 10.

Table 5 shows the estimated EF values of all heavy metals in dust samples collected from 25 schools in Kut city. Enrichment factor values are different for different metals. The highest enrichment factor is in the order of Pb > Co > Cd > Zn > Ni > Cr > Mn. The results indicate that dust samples in Kut city show a deficiency to minimal enrichment ($EF < 2$) of Mn (in all schools), while Co, Zn, Ni, Cr, and Cd are significantly enriched ($5 \leq EF < 20$), and very high enrichment ($20 \leq EF < 40$) by the Pb element.

According to Table 6, the enrichment factor value shows that 24% of cadmium samples and 4% of nickel samples were in the moderate contamination class. Also, 100% of zinc, cobalt, and chromium samples, 96% of nickel samples, 40% of cadmium samples, and 8% of lead samples were in the high contamination class. 36% of cadmium samples and 80% of lead samples were in the very high contamination class, and 12% of lead samples were in the extremely high contamination class. In other words, the dust in the city of Kut is very polluted with lead and highly

Table 6. The statistical results of the enrichment factor (EF) of heavy metals in 25 schools' dust samples in Kut city.

	EF values			
Heavy metals	Mean	Minimum	Maximum	Std.Dev.
Pb	32	18.6	84	13.931
Ni	7.25	4.87	12.87	1.717
Cr	7.09	4.36	12.6	1.613
Cd	5.75	2.76	38.37	12.085
Zn	11.87	9.25	14.37	1.377
Co	15	10.5	19.5	2.831
Mn	1.43	0.55	1.82	0.294

polluted with zinc, cobalt, chromium, and nickel metals. The higher amount of EF in the study items may have been related to anthropogenic inputs.

The study of indoor dust pollution at the Faculty of Science at Anbar University in Iraq is one of the leading studies in assessing heavy metal levels, with results revealing very high levels of lead and cadmium pollution (with CF values of 7.37 and 7.50, respectively). This is mainly attributed to the proximity to the university entrance and car parks, making vehicle emissions (car exhaust, tyre wear, and oil) the primary human source, while other metals (zinc and cobalt) showed moderate contamination from both human and natural sources. while pollution was negligible in chromium and copper from natural sources. Statistical analyses confirmed that outdoor dust is the main contributor to this pollution, with open ventilation systems in buildings and laboratory activities contributing to the transfer of these pollutants indoors.[43] The study of household dust pollution in Ramadi, Iraq, is an important piece of research that focused on assessing the levels of six heavy metals (zinc, nickel, copper, lead, chromium, and cadmium) in dust samples collected from 35 homes. The results showed that the average concentrations of all these metals were below the levels permitted in global guidelines, and the contamination factors (CF) showed values below 1, indicating minimal contamination. However, enrichment factors (EF) revealed moderate to significant contamination with nickel (6.35) and copper (5.40), mainly attributable to indoor human sources such as indoor smoking and the use of non-stainless alloy utensils and cookware, while levels of other metals were low. Multivariate statistical analyses confirmed that the sources of chromium, copper, nickel, and zinc are internal human sources related to domestic activities, while the sources of cadmium and lead are external and mainly caused by vehicle emissions and traffic, reflecting a generally acceptable environmental situation in the city compared to other Iraqi cities such as Fallujah.[44]

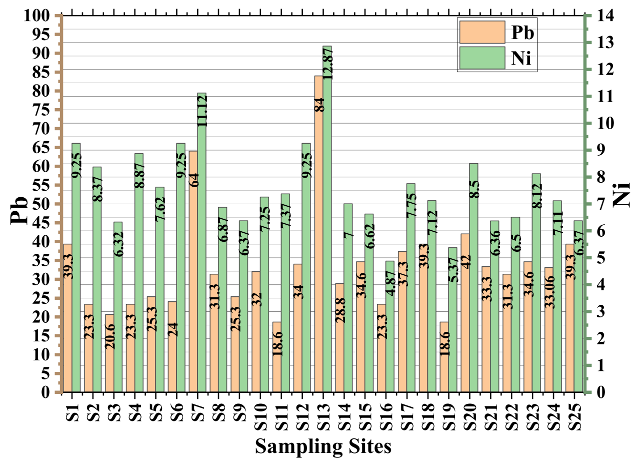

Fig. 11. Spatial distribution of EF of Pb and Ni in the study area.

The results of EF of Almola *et al.*,[45] showed that human pollution sources are linked to Cr, Cu, Zn, As, Se, Cd, Sb, Hg, and Pb. While Mn, Fe, and Ni come from natural sources, it is indicated to be attributable to the density of traffic, the activities of people, and the materials used on the surfaces of the roads in the area. In the study of Khurshid *et al.*,[46] during the investigation of contaminated urban soil in Kirkuk city, Pollution indices revealed a moderate level of contamination of lead, cadmium, and nickel, and a high level of contamination of arsenic and Mercury in all samples under the study sites.

Furthermore, spatial distribution of EF of Pb shows that the highest enrichment factor is found in schools number 13 (84), 7 (64) and 1 (39.3), which is significantly higher than other schools Fig. 11. Also, the enrichment factor of Ni shows highest values in schools No. 13 (12.87), 7 (11.12), 6(9.25), and 1 (9.25), as shown in Fig. 11.

The same trend exists in the case of Cr, and its enrichment factor values are 12.6, 10.18, and 8.63 in schools No. 13, 7, and 1 Fig. 12. The process of changes in the enrichment factor is different in other schools. The highest amount of Zn enrichment factor was in schools 13 (14.37), 24 (14.25), 8 (14.12), and 1 (13.37). The highest amount of Co enrichment factor is also in schools 17 (19.5), 8 (19), 4 (18.5), and 24 (18), while the highest values of the Cd enrichment factor were recorded in schools 14 (38.37) and 24 (37.58) as illustrated in Fig. 13. Mn enrichment factor has the highest values in schools 23 (1.82), 18 (1.77), 12 (1.77), and 22 (1.72) Fig. 14.

Pollution Load Index (PLI)

PLI is an easy tool to identify the number of times when the concentration of the heavy metals in soil exceeds the background value at a specific sampling location.[47] In this study, the PLI values are in the

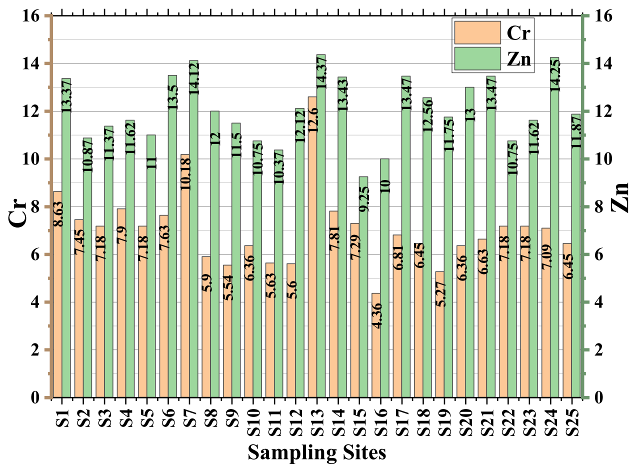

Fig. 12. Spatial distribution of EF of Cr and Cr in the study area.

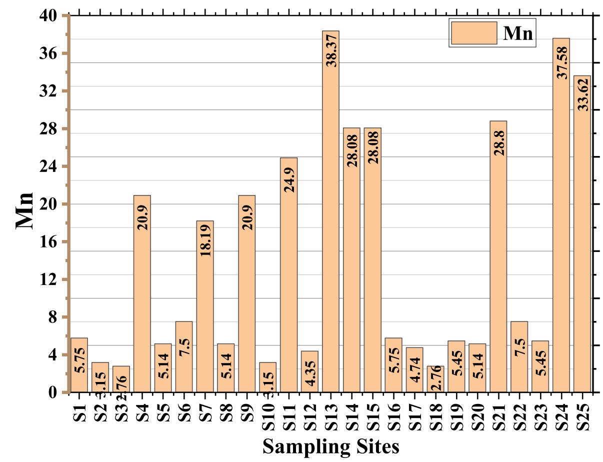

Fig. 14. Spatial distribution of EF of Mn in the study area.

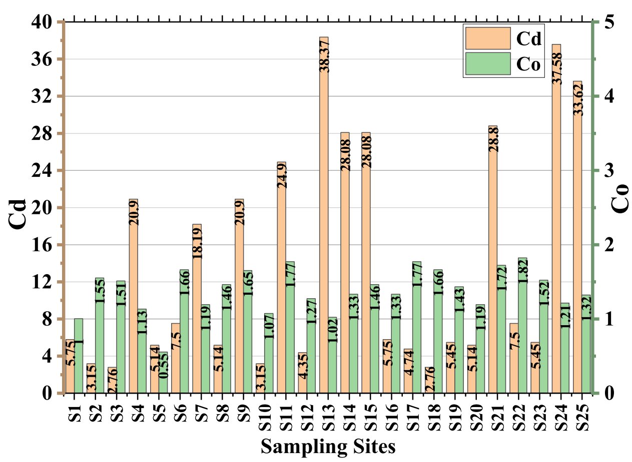

Fig. 13. Spatial distribution of EF of Cd and Co in the study area.

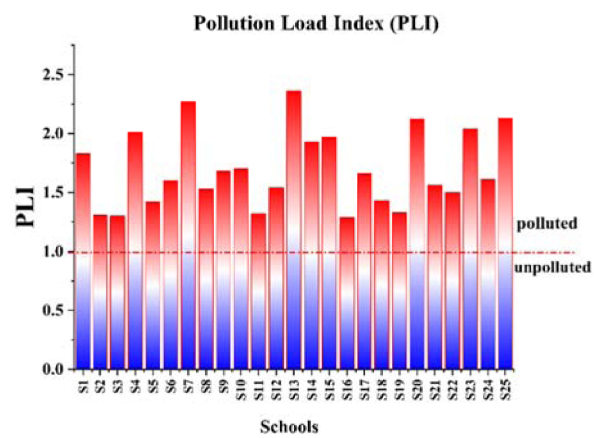

Fig. 15. Spatial variation of PLI of heavy metals in the school dust of Kut city.

Table 7. PLI values of heavy metals in 25 school dust of Kut City.

Statistical analysis	Mean	Minimum	Maximum	Std.Dev.
PLI values	1.61	1.29	2.36	± 0.318

range of 1.29 - 2.36, and 100% of the sampling points are in the contaminated class (deterioration on site quality) as listed in Table 7.

Also, Fig. 15 shows the spatial distribution of PLI values in the 25 study schools in Kut city. The highest pollution load index values are observed in schools No. 13 (2.36), 7(2.27), 25 (2.13), 20 (2.12), and 23 (2.04). The lowest pollution load index values are observed in schools No. 11 (1.32), 3 (1.3), and 16 (1.29).

According to Gurumurthy and Venkatachalapaddy,[48] the pollution load index values vary from zero (unpolluted) to 10 (highly polluted), with values smaller than one typically indicating no contamination and values larger than one indicating heavy metal contamination.

Okoro *et al.*[16] stated that PLI values of >1 indicate the need for immediate review to reduce contamination, PLI <1 <0.5 indicates that minor studies for site monitoring should be conducted, and PLI values <0.5 indicate that no drastic remedial action is needed. The findings of the research by Almola *et al.*[45] on street dust of 20 sites in Mosul City showed that 50 % of the PLI values for street dust are below 1, and therefore the studied region is considered unpolluted. Moreover, Mostafa *et al.*[49] were found that the pollutant load index (PLI) of all sampling sites exceeded the limit, and it denotes the decline in the quality of road-dust sediments because of their pollution by heavy metals, where the Cairo University St., Tahrir St., and Ramses St. showed the highest PLI values and the maximum was recorded in Ramses St, these locations experience extremely high traffic levels besides existence of the railway line as well as the unplanned bus-stations surrounding it thus has become a problem to the Egyptian capital by discharging pollutants through atmospheric emissions, which attach to fine particles to form dust and hence there is an accumulation to the roadside soil and vegetation. The findings of these researchers showed that the PLI values are in the moderate pollution category and indicate the role of human factors in the pollution of the area. The results of this study are also consistent with the work of Unsal *et al.*[50] where dust was collected from 22 schools in Vilnius. The value of PLI shows high pollution levels, indicating worsening environmental conditions in these areas.

A study in Erbil city conducted on women and children to reveal the impact of indoor exposures to heavy metals, Pb was found to be in low concentration in all studied sites, indicating minimal or low health risk. Although some locations show a slight elevation in concentration of Cr, As, and Cd compared to other study but still, the health hazard index was still below the threshold.[39]

The high PLI and CF noted, especially for Pb and Cd, indicate a considerable pollution level that extends beyond the ecological risk to represent health hazard. Modern studies have continued to point out that children are at an increased risk of heavy metal exposure partly through greater hand-to-mouth activity,[51] a higher degree of intestinal absorption and immature neurological systems.[52] Indicators such as CF can be considered the main index for exposure level. Thus, while the "significant to very high" contamination observed in the present study is not just a geochemical categorization but suggests a potentially elevated health risk situation particularly for children and warrants further exposure assessment with focused intervention.

Conclusion

This paper aimed to report levels of metals and contamination factor (CF), enrichment factor (EF), and pollution load index in indoor dust collected from 25 primary schools and kindergartens. Based on the pollution factor, the level of zinc, nickel, cobalt, chromium, and cadmium pollution in the dust of the study area is medium, and the level of lead pollution in the study area is medium to very high. PCA analysis revealed that anthropogenic activity (traffic, automobile repair industry waste and paints and pigments), natural (dust storm loaded with particles that are raised from soil erosion), and mixed sources are the main cause of increasing the levels of heavy metals in the air of schools and kindergartens.

Based on the enrichment factor, the dust of Kut city is polluted with Pb metal and highly polluted with Zn, Co, Cr, and Ni metals. It is suggested that in future studies, in addition to ecological indicators, health risk and the probability of developing cancerous and non-cancerous diseases in different age groups should be examined.

The results of this study could be used to reduce the metal levels in dust in educational buildings and improve its air quality, and such action is important for the health of children plus employees working in these structures.

In short, Al-Kut faces interrelated challenges including unplanned expansion, an inefficient transport network, and environmental pollution, which call for integrated solutions such as building additional bridges, improving road planning, encouraging public transport, and shifting towards vertical construction and mixed land use to achieve more sustainable urban development.

Acknowledgment

The authors extend their sincere thanks to the staff of the Central Environmental Laboratory for providing the opportunity and support to conduct this research. This work was conducted under a cooperation agreement between the University of Wasit and the Iraqi Ministry of Environment.

Authors' declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images that are not ours have been included with the necessary permission for republication, which is attached to the manuscript
- No animal studies are present in the manuscript.
- No human studies are present in the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee at University of Wasit.

Authors' contribution statement

W.T.A. designed the study, collected the samples, and participated in writing the first draft. Z.Z.A. conducted the statistical analysis and reviewed the final draft. I.H.H. analyzed the samples, contributed to the interpretation of data, and participated in writing the first draft. All authors have reviewed and approved the final draft.

References

1. Méndez HJ, Harvey D, Huang T, McGrath J, Meer D, Burton JC. The lifetime of charged dust in the atmosphere. PNAS Nexus. 2022;1(5):1–8. https://doi.org/10.1093/pnasnexus/pgac220
2. Iwegbue CMA, Nwose N, Tesi GO, Olisah C, Ujam OT, Odali EW, *et al.* Concentrations, sources, and health risk assessment of metals in indoor dust collected from visual arts studios of selected tertiary institutions in Southern Nigeria. Environ Forensics. 2023;24(1–2):55–70. https://doi.org/10.1080/15275922.2021.1940379
3. Aguilera A, Armendariz C, Quintana P, García-Oliva F, Bautista F. Influence of Land Use and Road Type on the Elemental Composition of Urban Dust in a Mexican Metropolitan Area. Pol J Environ Stud. 2019;28(3):1535–47. https://doi.org/10.15244/pjoes/90358
4. Castillo-Nava D, Elias-Santos M, López-Chuken UJ, Valdés-González A, de la Riva-Solís LG, Vargas-Pérez MP, *et al.* Heavy metals (lead, cadmium and zinc) from street dust in Monterrey, Mexico: ecological risk index. Int J Environ Sci Technol. 2020;17(6):3231–40. https://doi.org/10.1007/s13762-020-02649-5
5. Zheng N, Liu J, Wang Q, Liang Z. Health risk assessment of heavy metal exposure to street dust in the zinc smelting district, Northeast of China. Sci Total Environ. 2010;408(4):726–33. https://doi.org/10.1016/j.scitotenv.2009.10.075
6. Hu X, Zhang Y, Luo J, Wang T, Lian H, Ding Z. Bioaccessibility and health risk of arsenic, mercury and other metals in urban street dusts from a mega-city, Nanjing, China. Environ Pollut. 2011;159(5):1215–21. https://doi.org/10.1016/j.envpol.2011.01.03
7. Tashakor M, Behrooz RD, Asvad SR, Kaskaoutis DG. Tracing of Heavy Metals Embedded in Indoor Dust Particles from the Industrial City of Asaluyeh, South of Iran. Int J Environ Res Public Health. 2022;19:7905. https://doi.org/10.3390/ijerph19137905
8. Akhtar N, Syakir Ishak MI, Bhawani SA, Umar K. Various Natural and Anthropogenic Factors Responsible for Water Quality Degradation: A Review. Water. 2021;13(19):2660. https://doi.org/10.3390/w13192660
9. Bermúdez MDCR, Chakraborty R, Cameron RW, Inkson BJ, Martin MV. A Practical Green Infrastructure Intervention to Mitigate Air Pollution in a UK School Playground. Sustainability (Switzerland). 2023;15(2):1075. https://doi.org/10.3390/su15021075
10. Feng R, Liu M. Ecological Risk Assessment of Typical Heavy Metals in Surface Dust in Z University. IOP Conf Ser Earth Environ Sci. 2021;657(1):012047. https://doi.org/10.1088/1755-1315/657/1/012047
11. Unsal MH, Ignatavičius G, Valiulis A, Prokopciuk N, Valskienė R, Valskys V. Assessment of Heavy Metal Contamination in Dust in Vilnius Schools: Source Identification, Pollution Levels, and Potential Health Risks for Children. Toxics. 2024;12(3):224. https://doi.org/10.3390/toxics12030224
12. Khan SA, Muhammad S, Nazir S, Shah FA. Heavy metals bounded to particulate matter in the residential and industrial sites of Islamabad, Pakistan: Implications for non-cancer and cancer risks. Environ Technol Innov. 2020;19:100822.https://doi.org/10.1016/j.eti.2020.100822
13. Briffa J, Sinagra E, Blundell R. Heavy metal pollution in the environment and their toxicological effects on humans. Heliyon. 2020;6(9):e04691. https://doi.org/10.1016/j.heliyon.2020.e04691
14. Kumari S, Jain MK, Elumalai SP. Assessment of Pollution and Health Risks of Heavy Metals in Particulate Matter and Road Dust Along the Road Network of Dhanbad, India. J Health Pollut. 2021;11(29):1–14. https://doi.org/10.5696/2156-9614-11.29.210305
15. Al-Janabi ZZ, Hassan FM, Al-Obaidy AHMJ. Overall Index of Pollution (OIP) for Tigris River, Baghdad City, Iraq. Iraqi J Agric Sci. 2024;55(2):905–16. https://doi.org/10.36103/gqq14f43
16. Okoro HK, Orosun MM, Agboola AF, Emenike EC, Nanduri S, Kedia N, *et al.* Health risk assessments of heavy metals in dust samples collected from classrooms in Ilorin, Nigeria and its impact on public health. Heliyon. 2025;11(4):e42769. https://doi.org/10.1016/j.heliyon.2025.e42769
17. Berivan HM. Measurement of Fall Rate and Analysis of Atmospheric Falling Dust in Duhok Governorate of Iraq by Using Atomic Absorption Spectrometry and X-ray Diffraction. J Phys Conf Ser. 2021;1829(1):012001. https://doi.org/10.1088/1742-6596/1829/1/012001
18. Budai P, Clement A. Spatial distribution patterns of four traffic-emitted heavy metals in urban road dust and the resuspension of brake-emitted particles: Findings of a field study. Transp Res D Transp Environ. 2018;62:179–185. https://doi.org/10.1016/j.trd.2018.02.014
19. Al-Dulaimi TK, Al-Mallah AY. Comprehensive Evaluation of some Heavy Metals in Dust Deposited on Eucalyptus Tree Leaves and their Health Effects in Erbil City, Northern Iraq. Iraqi geol j. 2024;57(1):267–87. https://doi.org/10.46717/igj.57.1A.19ms-2024-1-30
20. Wang X, Liu E, Yan M, Zheng S, Fan Y, Sun Y, *et al.* Contamination and source apportionment of metals in urban road dust (Jinan, China) integrating the enrichment factor, receptor models (FA-NNC and PMF), local Moran's index, Pb isotopes and source-oriented health risk. Sci Total Environ. 2023;878:163211. https://doi.org/10.1016/j.scitotenv.2023.163211
21. Shen F, Mao L, Sun R, Du J, Tan Z, Ding M. Contamination Evaluation and Source Identification of Heavy Metals in the Sediments from the Lishui River Watershed, Southern China. Int J Environ. Res. Public Health. 2019;16(3):336. https://doi.org/10.3390/ijerph16030336
22. Haleem A, Amin S, Mahdi R. Assessment of health risk and geo-accumulation of toxic heavy metals in side-road dust from urban areas of Baghdad city. Public Health Toxicol. 2022;2(3):1–10. https://doi.org/10.18332/pht/153466
23. Radhi AB, Shartooh SM, Al-Heety EA. Heavy Metal Pollution and Sources in Dust from Primary Schools and Kindergartens in Ramadi City, Iraq. Iraqi J Sci. 2021;62(6):1816–28. https://doi.org/10.24996/ijs.2021.62.6.7
24. Al-Heety EAM, Yassin KH, Abd-Alsalaam S. Health risk assessment of some heavy metals in urban community garden soils of Baghdad City, Iraq. Hum Ecol Risk Assess. 2017;23(2):225–40. https://doi.org/10.1080/10807039.2016.1238301
25. Sezgin N, Ozcan HK, Demir G, Nemlioglu S, Bayat C. Determination of heavy metal concentrations in street dusts in Istanbul E-5 highway. Environ Int. 2004;29(7):979–85. https://doi.org/10.1016/S0160-4120(03)00075-8
26. Mohammed Z, Ziboon A, Kamal A, Alfaraj M. Urban air quality evaluation over Kut city using field survey and Geomatic techniques. MATEC Web Conf. 2018;162:05023. https://doi.org/10.1051/matecconf/201816205023
27. Sanarya Burhan Ahmed. The Domino Effect: Air Pollution And Human Health In Iraq, Sources And Effects. Redvet. 2024;25(1):717–25.

28. Nidhala HK, Ryadh YK, Shurouq JJ. Estimation the Radioactive Pollution by Uranium in the Soil of Al-Kut. Baghdad Sci J. 2011;8(2):13. https://doi.org/10.21123/bsj.2011.8.2.532-537
29. Jasim IA, Hasan HM, Farhan SL, Bahat KH. Evaluating the urban structure of Al-Kut city according to sustainability. IOP Conf Ser Earth Environ Sci. 2021;779(1):012021. https://doi.org/10.1088/1755-1315/779/1/012021
30. Cabrera F, Ariza J, Madejón P, Madejón E, Murillo JM. Mercury and other trace elements in soils affected by the mine tailing spill in Aznalcóllar (SW Spain). Sci Total Environ. 2008;390(2–3):311–22. https://doi.org/10.1016/j.scitotenv.2007.10.002
31. USEPA. Hazardous Waste Test Methods /SW-846 | US EPA. 2012.
32. Rozirwan, Az-Zahrah SAF, Khotimah NN, Nugroho RY, Putri WAE, Fauziyah, *et al.* Ecological Risk Assessment of Heavy Metal (Pb, Cu) Contamination in Water, Sediment, and Polychaeta (Neoleanira Tetragona) from Coastal Areas Affected by Aquaculture, Urban Rivers, and Ports in South Sumatra. J Ecol Eng. 2024;25(1):303–19. https://doi.org/10.12911/22998993/175365
33. Chen L, Zhang H, Ding M, Devlin AT, Wang P, Nie M, *et al.* Exploration of the variations and relationships between trace metal enrichment in dust and ecological risks associated with rapid urban expansion. Ecotoxicol Environ Saf. 2021;212:111944. https://doi.org/10.1016/j.ecoenv.2021.111944
34. Tomlinson DL, Wilson JG, Harris CR, Jeffrey DW. Problems in the assessment of heavy-metal levels in estuaries and the formation of a pollution index. Helgol. Meeresuntersuch ungen. 1980;33(1–4):566–75. https://doi.org/10.1007/BF02414780
35. He S, Li Y, Tang L, Yang F, Xie Y, Liu X, *et al.* Migration and Accumulation Mechanisms of Heavy Metals in Soil from Maoniuping Rare Earth Elements Mining, Southwest China. Land. 2025;14(3):611. https://doi.org/10.3390/land14030611
36. Zeng W, Wan X, Wang L, Lei M, Chen T, Gu G. Apportionment and location of heavy metal(loid)s pollution sources for soil and dust using the combination of principal component analysis, Geodetector, and multiple linear regression of distance. J Hazard Mater. 2022;438:129468. https://doi.org/10.1016/j.jhazmat.2022.129468
37. Ghazal NK. Monitoring dust storm using Normalized difference dust index (NDDI) and brightness temperature variation in Simi arid areas over Iraq. Iraqi J Physics. 2020;18(45):68–75.
38. Zgłobicki W, Telecka M. Heavy Metals in Urban Street Dust:Health Risk Assessment (Lublin City, E Poland). Applied Sciences [Internet]. 2021 Apr 30;11(9):4092. Available from: http://dx.doi.org/10.3390/app11094092
39. Shami NM, Yaba SP. Health Risk Assessment of Heavy Metals in Indoor Dust in Erbil City. ARO Sci J Koya Univ. 2025;XIII,(2):100–7. http://dx.doi.org/10.14500/aro.12215
40. Yan C, Wu Q, Li R, Liang Z, Yang Z, Zhu A, *et al.* Enrichment features, ecological risks assessment and quantitative sources appointment of sediment heavy metals: An example of the urbanized Xizhi River catchment, South China. J Environ Chem Ecotoxicol. 2025;7:263–74. https://doi.org/10.1016/j.enceco.2025.01.002
41. Heidari M, Darijani T, Alipour V. Heavy metal pollution of road dust in a city and its highly polluted suburb;quantitative source apportionment and source-specific ecological and health risk assessment. Chemosphere. 2021;273:129656. https://doi.org/10.1016/j.chemosphere.2021.129656
42. Hemati M., Rahimi G. Spatial Distribution and Contamination of Heavy Metals in Street Dust from Hamedan, Iran. Biomed J Sci Tech Res. 2020;30(1):22969–76. https://doi.org/10.26717/bjstr.2020.30.004882
43. Al-Rawi AS, Aljumialy AM, Saod WM, Al-Heety EA. Pollution Level and Sources of Heavy Metals in Indoor Dust from College of Science, University of Anbar Campus, Iraq. IOP Conference Series: Earth and Environmental Science [Internet]. 2024 Feb 1;1300(1):012019. http://dx.doi.org/10.1088/1755-1315/1300/1/012019
44. Ibrahim FK, Mustafa HK, Mohammed A A, Al-Heety E. Concentration, Pollution Level, and Sources of Heavy Metals from Household Dust in Ramadi City, Iraq. Asian J Water Environ Pollut. [Internet]. 2024 Jun 4;21(3):35. http://dx.doi.org/10.3233/ajw240032
45. Almola MA, Al-Ahmady KK, Mhemid RKS. An Investigation of Microplastic Occurrence and Heavy Metals Concentrations in Street Dust on the Left Side of Mosul City, Iraq. J Ecol Eng. 2024;25(9):116–32. https://doi.org/10.12911/22998993/190288
46. Khurshid CA, Mahdi K, Ahmed OI, Osman R, Rahman M, Ritsema C. Assessment of Potentially Toxic Elements in the Urban Soil and Plants of Kirkuk City in Iraq. Sustainability (Switzerland). 2022;14(9):5655. https://doi.org/10.3390/su14095655
47. Moldovan A, Török AI, Kovacs E, Cadar O, Mirea IC, Micle V. Metal Contents and Pollution Indices Assessment of Surface Water, Soil, and Sediment from the Arieș River Basin Mining Area, Romania. Sustainability. 2022;14(13):8024. https://doi.org/10.3390/su14138024
48. Kaliyamoorthi G, Venkatachalapathy R. Spatial and Seasonal Trend of Trace Metals and Ecological Risk Assessment along Kanyakumari Coastal Sediments, Southern India. Pollution. 2016;2(3):269–87. https://doi.org/10.7508/pj.2016.03.003
49. Mostafa MT, El-Nady H, Gomaa RM, Abdelgawad HF, Abdelhafiz MA, Salman SAE, *et al.* Urban geochemistry of heavy metals in road dust from Cairo megacity, Egypt: enrichment, sources, contamination, and health risks. Environ Earth Sci, 2024;83(1):1–22. https://doi.org/10.1007/s12665-023-11342-y
50. Unsal MH, Ignatavičius G, Valiulis A, Prokopciuk N, Valskienė R, Valskys V. Assessment of Heavy Metal Contamination in Dust in Vilnius Schools: Source Identification, Pollution Levels, and Potential Health Risks for Children. Toxics. 2024;12(3):224. https://doi.org/10.3390/toxics12030224
51. Ngo HTT, Watchalayann P, Nguyen DB, Doan HN, Liang L. Environmental health risk assessment of heavy metal exposure among children living in an informal e-waste processing village in Viet Nam. Sci Total Environ. 2021 Apr;763:142982. http://dx.doi.org/10.1016/j.scitotenv.2020.142982
52. Yang Q, Zhang L, Wang H, Martín JD. Bioavailability and health risk of toxic heavy metals (As, Hg, Pb and Cd) in urban soils: A Monte Carlo simulation approach. Environ Res. 2022 Nov 1;214:113772. https://doi.org/10.1016/j.envres.2022.113772

تقييم المخاطر الصحية البيئية لبعض العناصر الثقيلة في غبار بعض رياض اطفال والمدارس الابتدائية في مدينة الكوت، العراق

وسام ثامر المياح[1]، زهراء زهراو الجنابي[2]، عصام هاني حميد[1]

[1]قسم علوم التربة والموارد المائية، كلية الزراعة، جامعة واسط، واسط، العراق.
[2]مركز البحوث البيئية، الجامعة التكنولوجية، بغداد، العراق.

الخلاصة

تُعد المعادن الثقيلة في الغبار من أهم الآثار البيئية الناجمة عن الأنشطة البشرية. تهدف هذه الدراسة إلى تقييم المخاطر البيئية للمعادن الثقيلة على صحة الإنسان في غبار مدارس مدينة الكوت، العراق. جُمِعت عينات الغبار من 25 مدرسة ابتدائية ورياض أطفال. تم قياس الاس الهيدروجيني (pH)، والتوصيلية الكهربائي (EC)، والمواد الصلبة الذائبة الكلية (TDS)، وتراكيز المعادن الثقيلة (الرصاص Pb، النيكل Ni، الكروم Cr، الكادميوم Cd، الزنك Zn، الكوبلت Co، المنغنيز Mn). تم قياس تراكيز المعادن الثقيلة باستخدام جهاز مطياف الامتصاص الذري. وتم حساب عامل التلوث (CF)، وعامل الإثراء (EF)، ومؤشر حمل التلوث (PLI). أظهرت النتائج أن معدل تركيز الرصاص (Pb)، والنيكل (Ni)، والكروم (Cr)، والكادميوم (Cd)، والزنك (Zn)، والكوبلت (Co)، والمنغنيز (Mn) في غبار المدارس كان 37، 45، 60، 0.15، 37، 24، 110 ملغم/كغم على التوالي. كان معدل تركيز جميع المعادن الثقيلة أعلى من قيم المسموح بها لهذه المعادن، باستثناء المنغنيز (Mn) والنيكل (Ni).

سُجلت أعلى تراكيز من الرصاص (Pb)، والنيكل (Ni)، والكروم (Cr) في المدارس رقم 13، 7، و1 على التوالي. كما كان مقدار الكادميوم (Cd) أعلى بشكل ملحوظ في المدارس رقم 13، 7، و23 مقارنة بالمدارس الأخرى. يُشير الارتباط المعنوي الواضح بين المعادن الثقيلة إلى أن هذه المعادن تنتمي إلى مصدر واحد. كان عامل التلوث (CF) لمعظم المعادن الثقيلة يقع ضمن فئة التلوث المتوسط ($1 \leq CF < 3$). أما عامل الإثراء (EF) فكان في معظم العناصر ضمن فئة الإثراء الكبير ($5 \leq EF < 20$). تراوحت قيم مؤشر حمل التلوث (PLI) بين 1.29 , 2.36، وقد وقعت 100٪ من مواقع أخذ العينات ضمن الفئة الملوثة.

الكلمات المفتاحية: تلوث الغبار، المعادن الثقيلة، تحليل المكونات الرئيسية، معامل ارتباط بارسون، المدارس الابتدائية، دلائل تلوث التربة.