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A RECONNAISSANCE SURVEY OF HEAVY METALS CONCENTRATION IN STREET DUST OF THE HILLA CITY, MIDDLE OF IRAQ

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Abstract

The heavy metal content of road dust samples from 13 representative sites in Hilla City which areis detailed below. We look at Fe, Mn, Pb, Cu, Ni, Zn, As, Co, V, Hg, Sr, Zr, and Cr in this study. Following sample collection, drying, sieving, and preparation, the concentrations of these metals were evaluated using X-Ray Fluorescence (XRF) spectrometry. Heavy metal concentrations varied greatly in space, and statistical results showed that different metals were weakly or moderately correlated, suggesting there were various sources of contamination. The groups identified through cluster analysis were two: one was all metals except Cu, likely formed naturally from soil and recent sediments, while the other was made up mainly of Cu from activities such as road traffic. Results from pollution assessment using Igeo revealed that Fe, Mn, V, Cr, and Zr are not present in excess in the study area. Cu, Zn, and Ni are moderately polluted, Co is moderately polluted, and Pb is strongly polluted relative to the background values of the area. On the other hand, figures from around the world revealed less pollution. The overall levels of pollution in each location suggest the main influence of additions to the environment from people's activities. Enrichment Factor (EF) finds Fe, Mn, V, Cu, and Zr are slightly enriched, while Cr, Ni, and Zn are moderately so. Pb was the metal with the greatest enrichment, and Co showed the greatest enrichment. All Ecological Risk Indexes (ERI) fell within low values, except for Pb, which was on the edge of becoming moderate. A similar result found that the Potential Ecological Risk (RI) index was considered low everywhere the samples were collected. The study showed high levels of pollution for Pb and Co, moderate pollution for Cu and Zn, and low pollution for Ni and Cr, using nearby background data. According to the results, activities caused by humans, such as vehicles and local industries, are major reasons why heavy metals end up in Hilla road dust. As a result, there is a risk to both the environment and people's health in crowded and well-travelled areas. As a result, useful methods for checking pollution and enforcing rules should be put in

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place to minimise both risks and pollution levels. Researchers should continue monitoring species over many years and in more parts of the world to support action for sustainability.

Keywords: Pollution Indices; Heavy Metals; Road Dust; Hilla City

1. Introduction

Heavy metals can be described as elements that exhibit metal characteristics and have an unstable electronic arrangement (Atkins & Jones, 1997). Because of their unstable orbital configuration, they contribute electrons with other elements to achieve equilibrium. Those metals that disengage freely will interact with the atmosphere, and some of them are dangerous to the environment or to health, such as chromium, cadmium, and lead (Al-Jaberi *et al.*, 2016; Al–Khafaji et al., 2024). A few of these elements might cause corrosion (e.g., lead and zinc), and some metals are harmful in other ways. In addition, some of them are essential for humans in small amounts (manganese, cobalt, nickel, copper and chromium), but others are carcinogenic substances or toxic, affecting, among others, the central nervous system (arsenic, manganese, mercury and lead) (Jasim et al., 2024) Heavy metals contamination may originate by several sources, but the greatest one usually originates by the refining of metals, such as smelting of copper, production of atomic fuels and electro-plating (Jasim et al., 2021). The environmental pollution with heavy metals can't be degraded by biological methods, but can be converted from one organic compound or oxidation form to another (Lone *et al*., 2008; Jing *et al*., 2007). Road dust is a combination of clay and silt particles that may contain several components like mold spores, heavy metals, organics, animal dander, and pollen fragments. Road dust gets suspended as a result of wind movement or vehicles, creating a significant source of atmospheric air contamination. The sources are car exhaust emissions and the wear of several vehicle fragments like tires and brake discs (Bilos *et al.*, 2001). It was noticed that the particles and related metals, especially the fine fraction, stay suspended in the air for along time, specific to meteorological situations. Road dust, a significant environmental index of metals pollution from atmospheric deposition, receives different inputs of anthropogenic metals from several constant and moving sources, for example, industrial activities, vehicular traffic, power plants, residential fossil fuel burning, waste incineration, resuspension of contaminated soil, construction, and demolition activities (Bilos *et al.*, 2001,& Salman *et al.*, 2020). In the present study, road dust samples were collected from Hilla City, which is the capital of Babil Province. It is located within the Mesopotamian Plain, about 100 km South of Baghdad, bound by Longitudes (44.466511 & 44.368836) and Latitudes (32.518875 & 32.425754). The city is situated in a predominantly agricultural region, which is widely irrigated with water provided by the Shat Al-Hilla River (Figure 1).

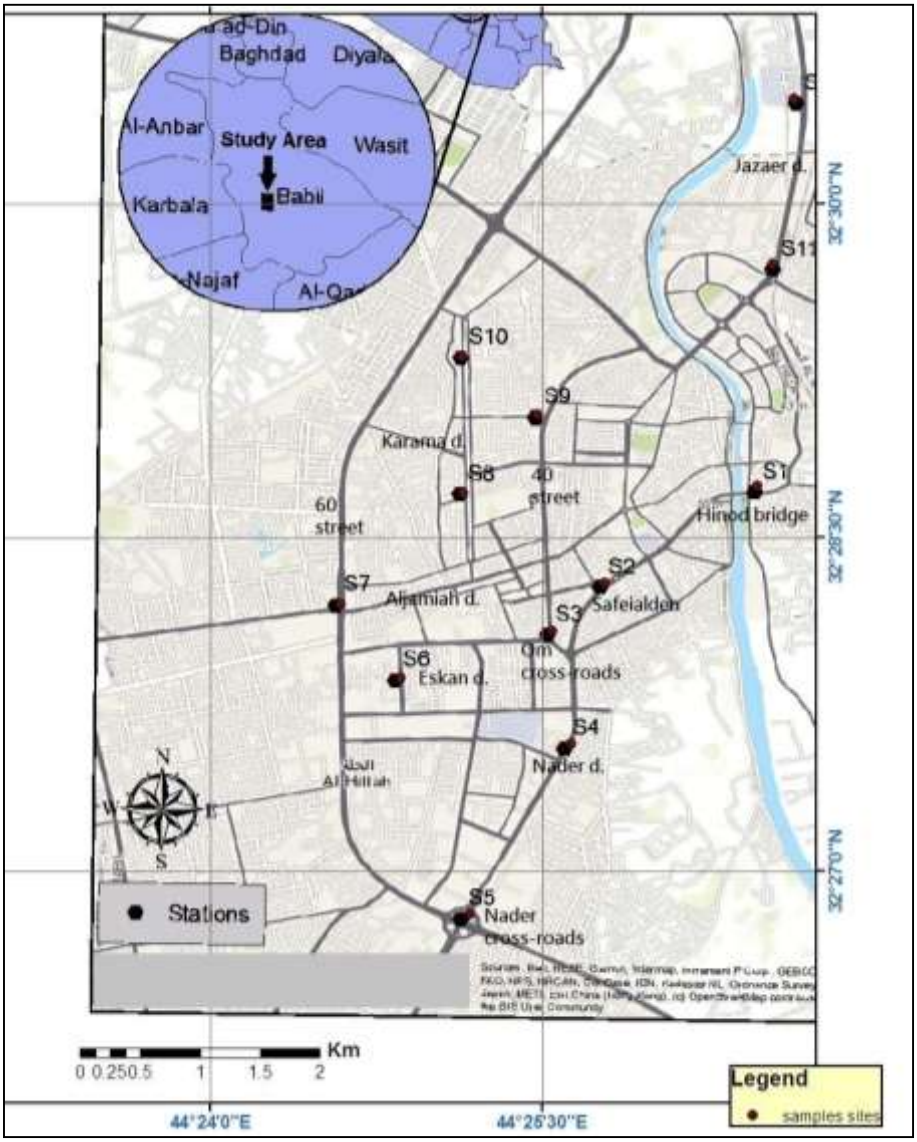

Figure 1. Location map of the study area and sampling stations.

2. State of the Art

Several studies have examined the distribution, sources, and environmental impact of heavy metals in water and soils. and sediments. These studies on road dust offer useful information for this study. Khoidem *et al.* (2009) studied the distribution of heavy metals in soils in Basra City, southern Iraq. The results showed high levels of contamination, particularly in urban and industrial areas, illustrating the role of human activity in the spread of heavy metals. Hana and Al-Bassa (1983) studied lead pollution contamination of air, soil, and vegetation in Baghdad city. Vehicle emissions, according to their study, were one of the primary causes of lead pollution in urban areas. Al-Bassam *et al.* (2009): Lead concentrations in dust were found to be higher in Baghdad City's industrial and high-traffic areas. The significance of keeping an eye on airborne particulates as markers of urban pollution was emphasized by this study. Al-Bassam and Yousif (2014) offered background values and detailed geochemical analysis of trace and minor elements in Iraqi sediments and soils. Their work provided baseline data,

which is important for determining pollution levels and results variation in both urban and rural settings. Hussain, S.H., & Manii, J.K. (2023) studied and plotted air pollution levels at the Al-Zubaydiah electrical power plant in Wasit Governorate, Iraq. The study shows an interest in analyzing industrial-related air pollution by focusing on pollutant spatial distribution and environmental effects. Salman, E.F., Muttelab, M.K., & Manii, J.K. (2020) showed radioactivity levels and heavy metal concentrations in soils in Najaf city. The study assist to understand soil contamination and its potential health risks.

The body of research demonstrates the ongoing heavy metal contamination problems in Iraqi urban areas. Changes must be implemented to monitor and reduce harmful effects, which mainly target densely populated areas and industrial zones. The research findings from previous studies provide a solid understanding to evaluate the heavy metal measurements within Hilla City.

3. Sampling and Analysis

In this study, the concentrations of (Ni, Pb, Fe, Mn, V, Cr, Cu, Co, As, Hg, Zr, Sr, and Zn) were analyzed in the road dust samples in Hilla city. The concentration of the reference metal Fe was estimated. Dust samples were collected from 13 sites having different features of urban settings in the city, including manufacturing, main road, residential, and varied-use areas. Sampling was made in 3 periods in the summer of 2020 to make a bulk sample. The samples were collected using a brush with a pan of plastic material and polyethylene bags. The samples were dried at110 C^0 in an oven for 24 h, sieved by a 200 mesh sieve to remove debris, plants, and other coarse materials, grind by agate mortar to a fine powder. The sieved dust samples were prepared and placed in an XRF Sample Cup after making sure that the material was dry, homogeneous, and non-cohesive. The heavy metals iron (Fe), manganese (Mn), arsenic (As), cobalt (Co), vanadium (V), mercury (Hg), strontium (Sr), zirconium (Zr), copper (Cu), zinc (Zn), lead (Pb) and chromium (Cr) were analysed in the University of Babylon, College of Science, Applied Geology Department, using Niton XRF analyzer after calibrating the device with standard samples.

4. Results and Data Processing

4.1. Comparison with Published Data

Mean analytical metal concentrations were compared against three different standards: Local Background reported by (Al-Bassam and Yousif,2014) for Iraqi soils. The analysis incorporated Earth crust average concentrations according to Taylor (1964) and average shale values according to Turekian and Wedepohl (1961).
Key observations include:

1-The natural geogenic origins of Iron (Fe) and Manganese (Mn) become evident through their concentrations being lower than regional and worldwide background values.

2-The concentrations of Lead (Pb) exceed area-specific limits as well as worldwide thresholds, which demonstrates its status as a primary source of air pollution.

3-The concentration of copper is at higher levels than regional standards but remains inferior to worldwide standards, which suggests anthropogenic emissions from local sources.

4- The concentration of Chromium (Cr); opposite to Cu, with concentrations higher than global but lower than local averages.

4.2. Main Statistical Parameters

The analytical results (Table 1) show that there is a high variation of the examined metals in dust samples. The Variation Coefficient (VC) is equal to: (standard deviation/ average value of the metal concentration). VC is very high for Pb (> 50), VC of Hg is 50 but the concentration is low, ranges between (1 – 7 mg/kg), Cu also shows high variation (VC > 40), As, Sr, Zr and Zn concentrations show medium VC (20 to 40), and Fe, Ni and Mn are show the lowest VC (Table 1). The higher value of VC indicate higher anthropogenic influence (Martin *et al.*, 2006).

Table 1. Mean, Median, Range, Standard Deviation, and Variation Coefficient (VC) of the analysed metals.

Metal	Fe	Mn	Pb	Cu	Ni	Zn	As	Hg	Zr	Sr
	Mg/kg	Mg/kg	Mg/kg	Mg/kg	Mg/kg	Mg/kg	Mg/kg	Mg/kg	Mg/kg	Mg/kg
Mean	16292	398	46	38	118	115	6	4	157	603
Median	15200	389	40	32	119	115	5	3	155	557
Max	20700	502	100	77	140	149	10	7	219	968
Min	12500	310	19	19	86	71	3	1	106	428
ST.de	3100	61	26	16	13	26	2	2	39	156
Vc	19	15	27	43	11	22	374	50	25	26

Many geochemical background values were used for correlation. Locally, for Iraq, the results are correlated with heavy metals concentration in soil reported in Al-Bassam and Yousif (2014), and globally the results were correlated with two references, first; average concentrations of Earth Crust to explain the enrichment of metals produced by anthropogenic activity (Nomaan *et al.*, 2012),(Al-Haidarey *et al*., 2010), (Akoto *et al.*, 2008) (Guimaraes *et al.*, 2011), (Yisa, *et al.*, 2012; Loska *et al.*, 2003; Kassir *et al.*, 2011, among others), and second; average shale values of heavy metals (Turekian &Wedepohle, 1961). Some metals were compared with the accepted concentration limits of the World Health Organization (WHO, 1996); the correlation charts show that Fe, Mn, V, and Zr concentrations are less than the background values, Cu is less than the global values but more than Iraqi background values, whereas the opposite is with Cr. While Pb, Co, Ni, Zn, and Sr show more than the global and local background values, and finally, As concentration is more than the crustal average but less than the shale average (Figures 2 and 3).

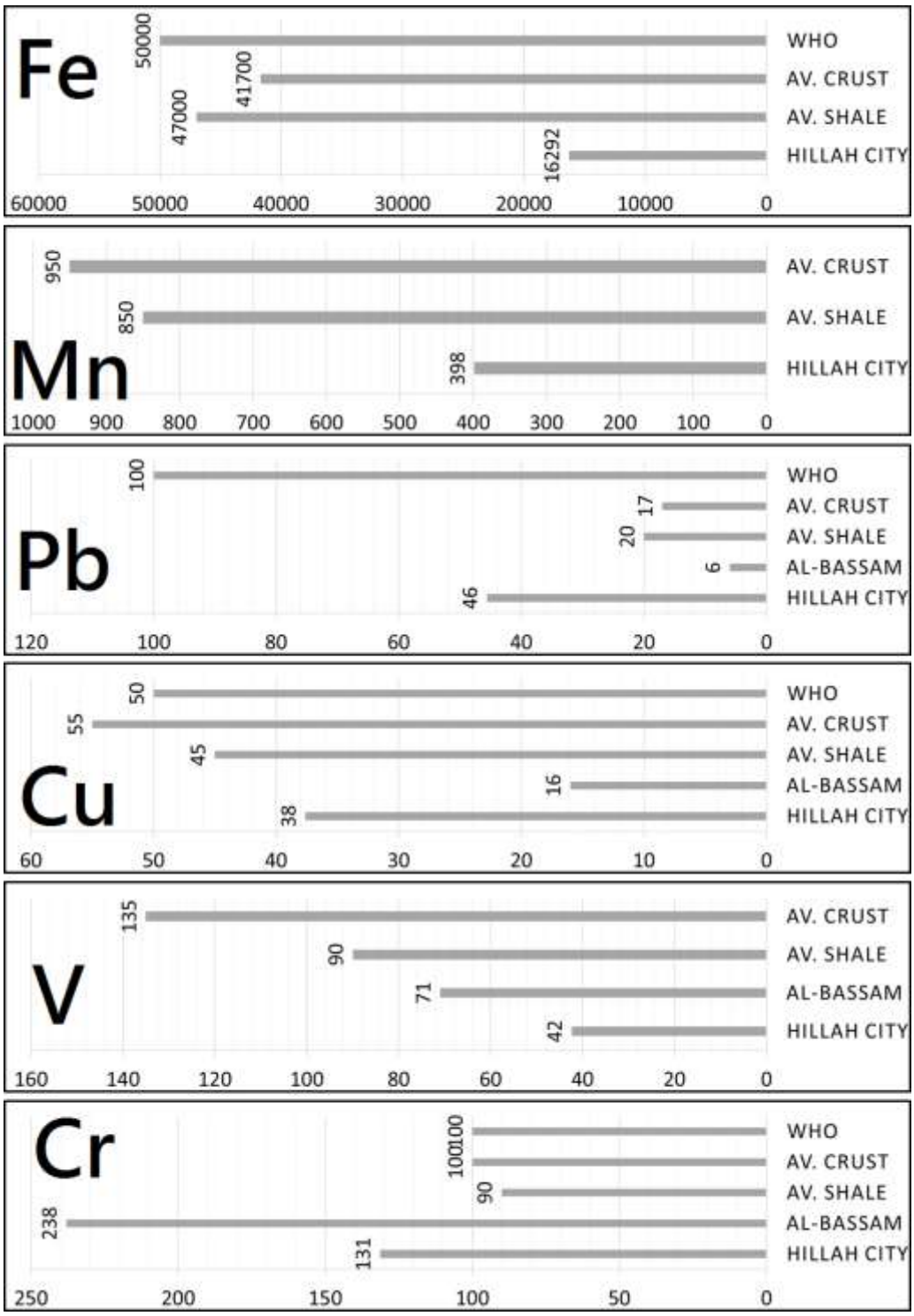

Figure 2. Correlation histograms between mean concentration values of heavy metals in the study area with local and global background values, the average shale from Turekian and Taylor (1964), the crust average from Taiwo et al. (2014), local values from Al-Bassam & Yousif (2014), and accepted limits of the WHO (1996).

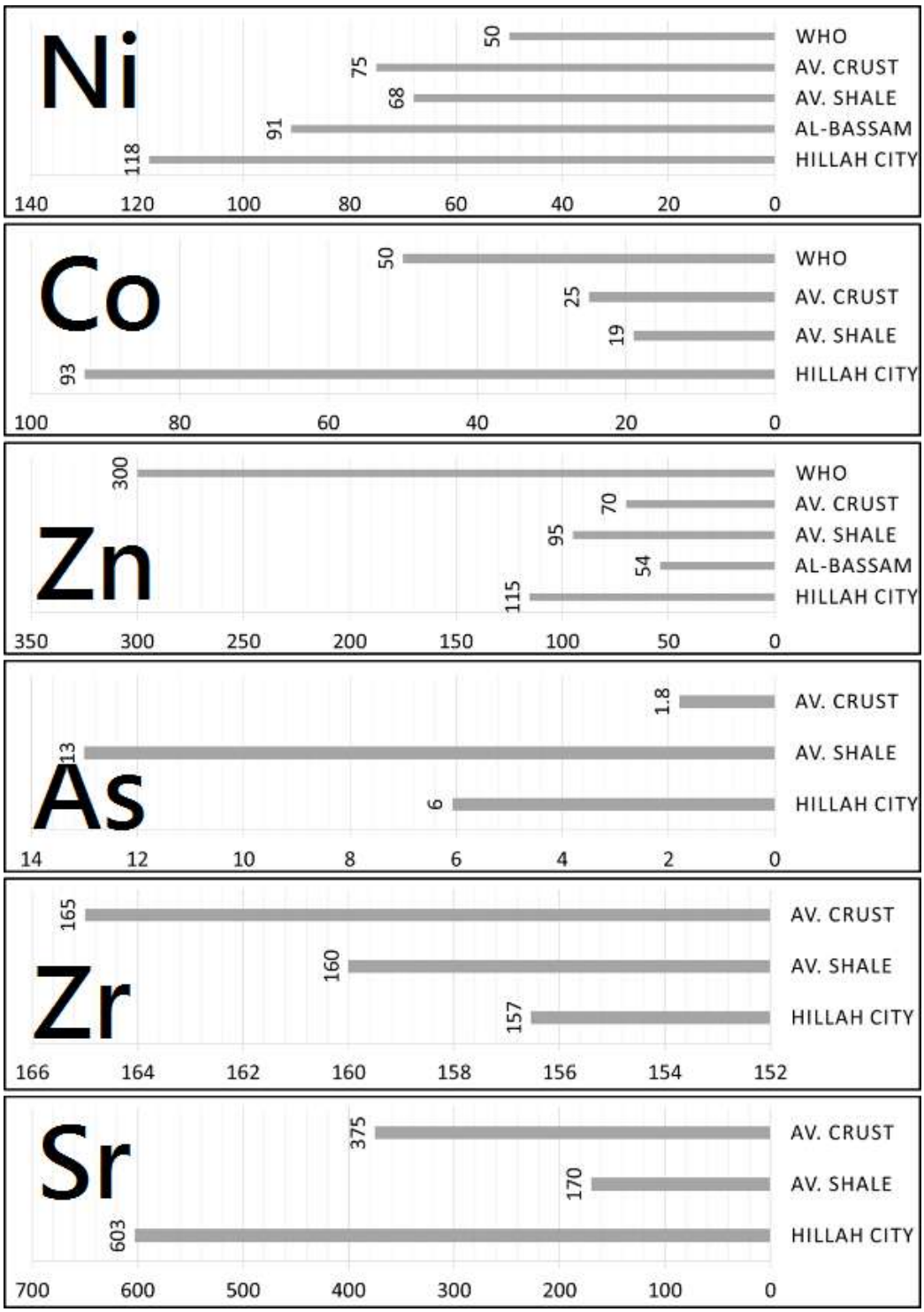

Figure 3. Correlation histograms between mean concentration values of heavy metals in the study area with local and global background values, the average shale from Turekian& Wedepohl (1961), the crust average from Taylor (1964), local values from Al-Bassam & Yousif (2014) and Hussain (2023), and the limited acceptance of WHO (1996).

To recognize the source of metals in the analysed road dust samples, statistical procedures were applied that allowed allocation of the considered metals into groups categorized by corresponding spatial variation forms. The data analysis methods included: Correlation Coefficient (CC) analysis and Cluster analysis (CA). The main relations are as follows: Fe and Mn show a very strong relation (CC = 0.86); Fe has a positive weak relation with V, Zn, As, and Hg, but moderate relations with Cr and Ni. Mn shows the same relation with Fe, and Pb has a strong relation with Zn, and a moderate relation with Sr. A moderate relation is shown between Cu and both Hg and Zr, and V with As, Ni, and Hg. Strong relation between Cr and As, and Zn with Sr. Strong negative relation between Zr and Sr (Table 2).

Cluster Analysis (CA) was achieved for a group of data with the purpose of detecting resemblances in the behavior of the geochemistry of the examined metals and to provide a clearer vision into the construction of the data. CA allows the locating of geometric, multidimensional Euclidean distances among the exact metals. The distances among data points were analyzed with the SPSS program using the Average Linkage (between groups) method (Figure 4), which shows the groups of data. The results show two groups of metals, perhaps produced from various sources. First; includes all metals except Cu. The source of these metals in road dust can be related mostly to natural geogenic sources, such as soil and recent sediments of the area. The second includes Cu, which is most probably transported to road dust from anthropogenic sources.

Table 2. Correlation matrix of heavy metals in road dust of Hilla City.

Fe	1.00										0.0-19	Very weak	
Mn	0.86	1.00									20-39	Weak	
Pb	0.04	-0.01	1.00								40-59	Moderate	
Cu	-0.11	0.08	0.11	1.00							60-79	Strong	
V	0.33	0.26	-0.10	-0.50	1.00						80-100	Very strong	
Cr	0.49	0.64	-0.21	-0.20	0.34	1.00							
Ni	0.49	0.47	-0.24	-0.13	0.38	0.39	1.00						
Co	0.11	0.14	-0.15	0.24	-0.11	-0.10	-0.37	1.00					
Zn	0.30	0.10	0.65	0.11	0.16	-0.34	0.12	0.06	1.00				
As	0.35	0.32	-0.14	-0.33	0.50	0.78	0.23	-0.33	-0.19	1.00			
Hg	0.33	0.37	-0.10	0.41	0.36	-0.06	0.48	-0.08	0.34	-0.05	1.00		
Zr	0.08	0.08	-0.09	0.45	-0.32	0.28	0.05	-0.13	-0.40	0.14	-0.09	1.00	
Sr	-0.05	-0.02	0.46	-0.13	0.08	-0.19	-0.07	0.17	0.61	-0.05	-0.10	-0.72	1.00

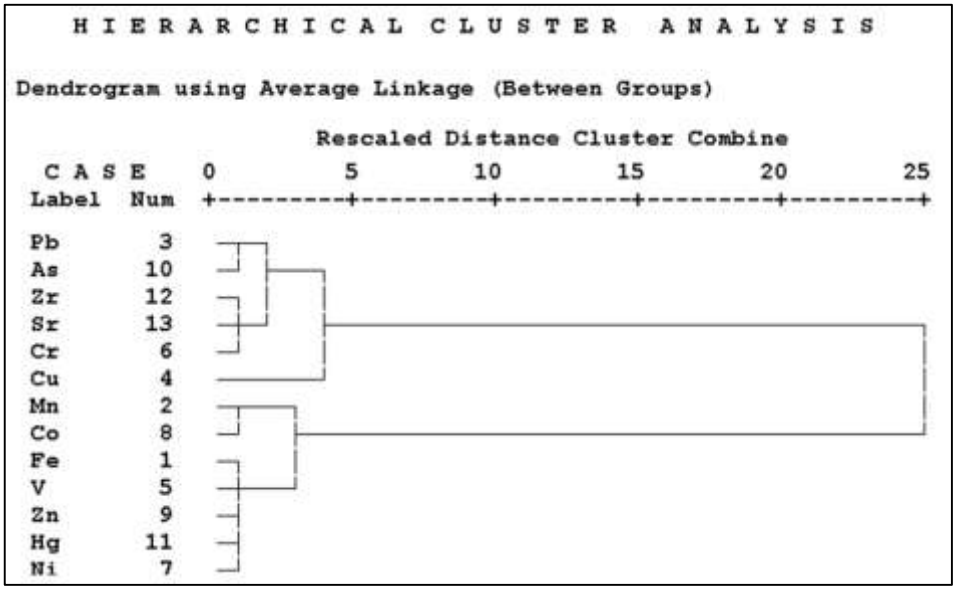

Figure 4. Dendogram (R-Mode) of metals in the road dust in Hilla City.

4.3. Spatial Distribution of Heavy Metals

The ArcGIS Geostatistical Analysis method was used in this study. Several sophisticated approaches can determine the properties of sets by a limited quantity of point measurements. Maps produced as shown in Figures 5, 6, and 7. Fe and Mn are showing nearly the same spatial distribution; both metals have a higher concentration in stations (S3, S4, S6, S10, and S13). They are situated on the main streets of the study area, nearly in the center of the study area (Figures 5B and 5A). Hg is showing the same spatial distribution of Fe and Mn (Figure 7B), but the concentration of Hg is very low, between 1 and 7 mg/kg, and has two hotspots at stations (S3 and S4). Zr has the highest concentration in the north and south of the city. In the south (station S5), there is one of the biggest cross-roads in the study area and near a lot of industrial activity (car and truck parts repair, welding industries, and iron and construction materials stores), but in the north (stations S11 and S12), there are near a fuel station and a hospital. Lower concentrations are observed in the center of the study area (Figure 6A).

Zinc (Zn) shows two hotspots, S3, which is in the center of the study area, characterized by high population, heavy traffic, and near a construction area, while S1 is a heavy traffic area, close to one of the main bridges in the city, and the rest of the study area shows less concentration distribution (Figure 6B). V concentration is centred precisely in the middle of the study area, with lower concentrations to the north, south, and east, two hotspots in the west (S6 and S10), where both are characterized by heavy population and traffic (Figure 6D). Sr concentration is higher in the east and west of the city; all stations (S1, S3, S7, S8, and S10) are heavy traffic areas, while the concentrations are lower in the north and south of the study area (Figure 6C). The spatial distribution of Pb is clearly shown in the heavy traffic areas, exactly in the center, main bridge, main fuel station, and construction area, as a result of car fuel that contains a high concentration of Pb (Kumar *et al.*, 2013). Another hotpot is located in the north, near another fuel station in the city, and another one near the crossroad in

the south (Figure 5C). Ni's spatial distribution is concentrated in the center, with the highest level near the construction area, with the other two hotspots, S12 near the fuel station in the north, and S4, in a heavy traffic area (Figure 5D). Cr shows the same spatial distribution over the study area with one hotspot in the north (S12), located near the fuel station and a hospital (Figure 7A). Finally, Cu is concentrated in the south and east of the study area, decreasing to the north and west; all hotspots of Cu are heavy traffic areas (Figure 7C).

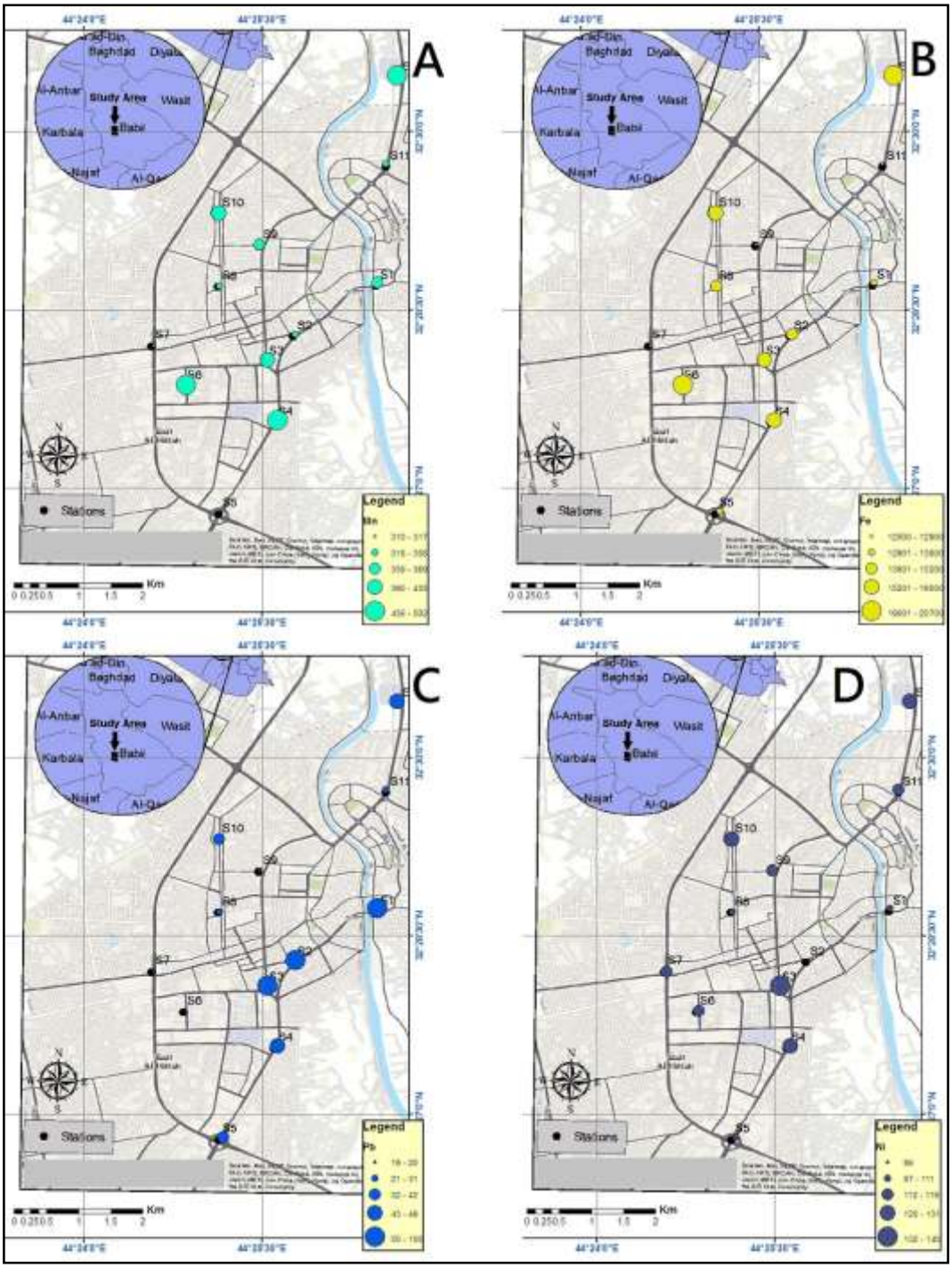

Figure 5. Spatial distribution of Fe, Mn, Pb, and Ni in Hilla City.

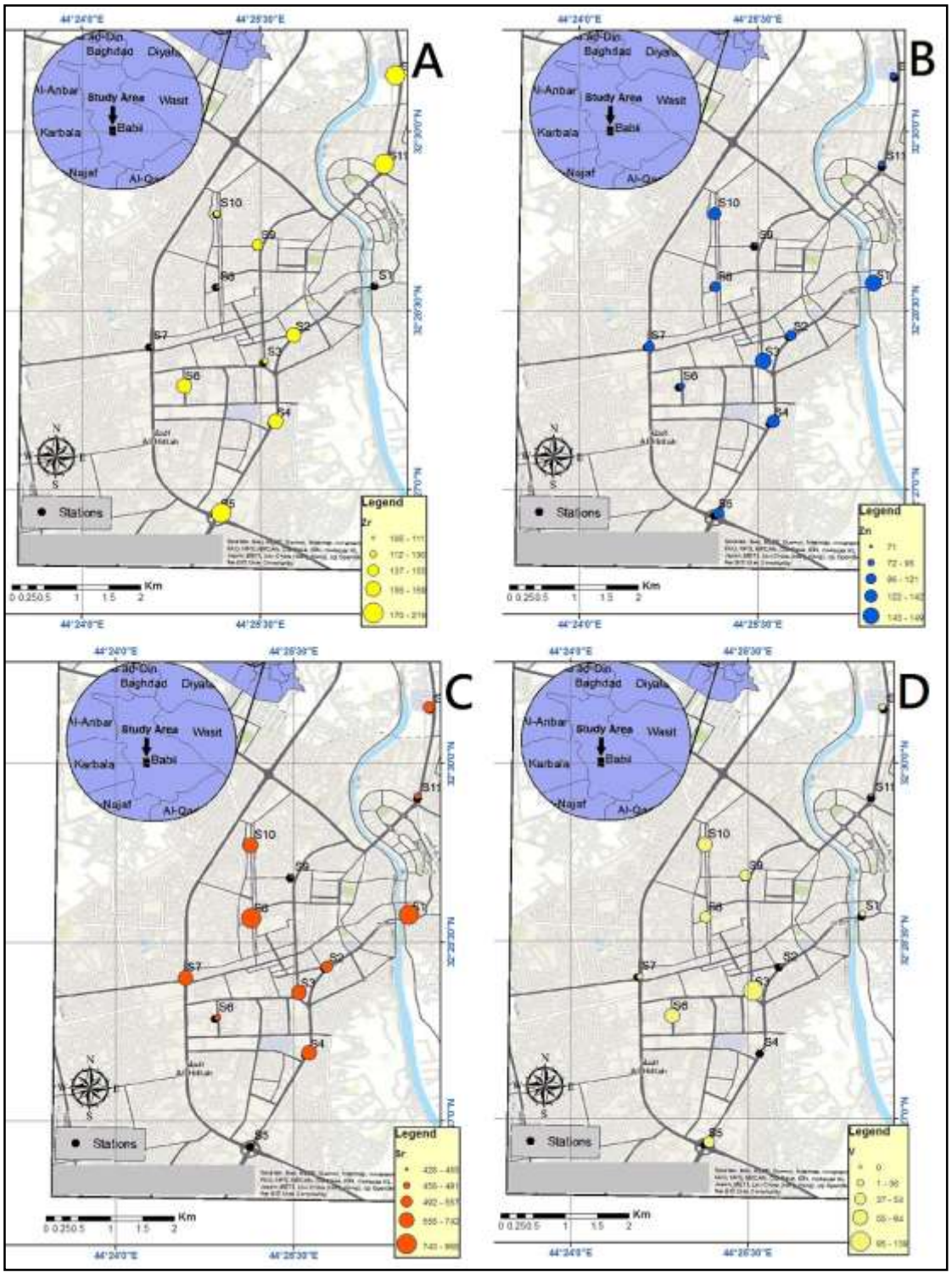

Figure 6. Spatial distribution of Zr, Zn, Sr, and V in Hilla City.

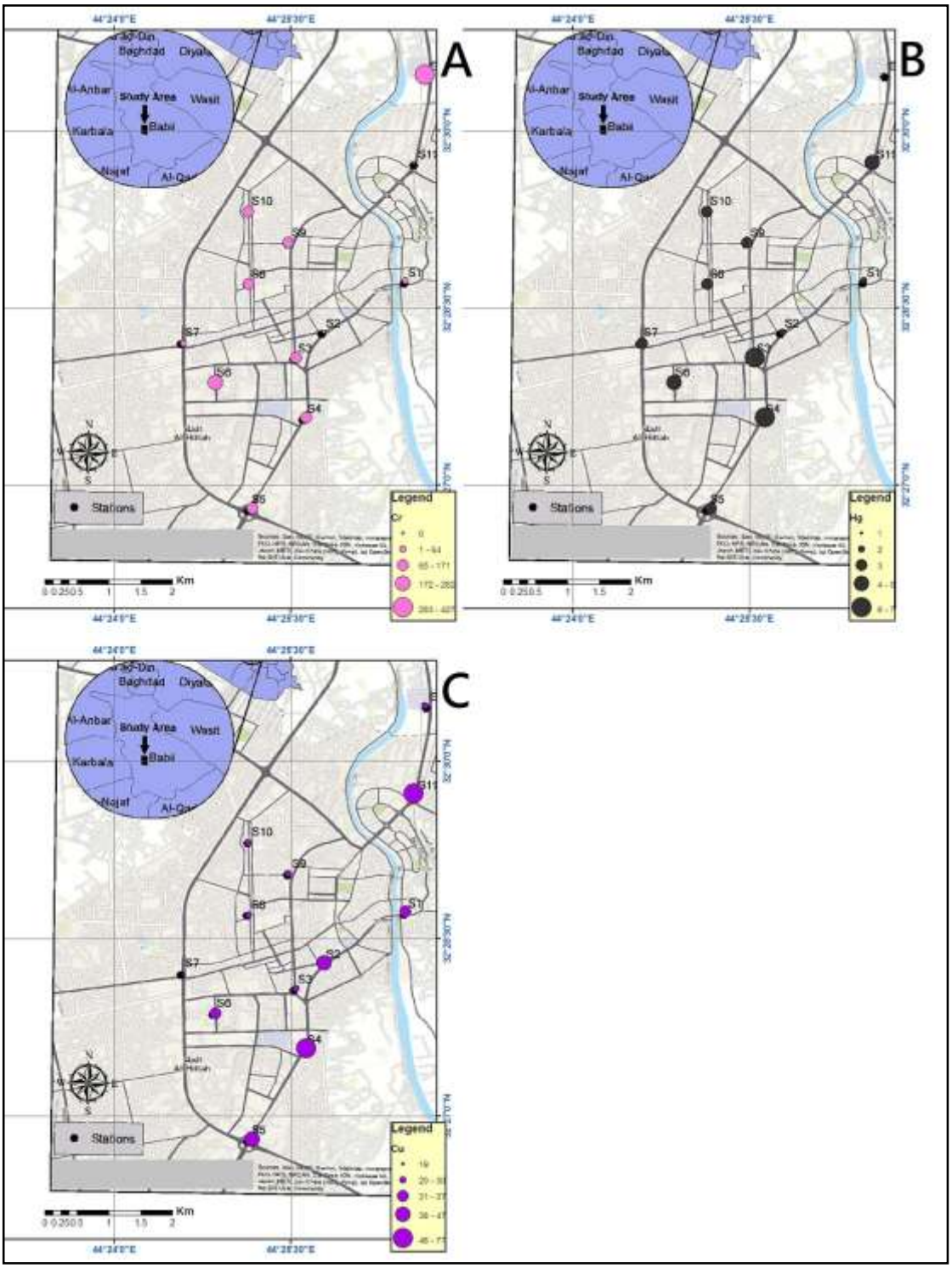

Figure 7. Spatial distribution of Cr, Hg, and Cu in theHilla City

4.4. Environmental Pollution Indices

4.4.1. Index of Geo-accumulation (Igeo)

First introduced by (Muller, 1979) for metals concentration in less than two-microliter portions and established for the worldwide typical shale standards, the formula is:

$$I_{geo}=\log_2 (C_n /1.5\ C_{ref}) \quad (1)$$

Where Cn is the concentration of metal n in the sample, Cref is the background value of the metal n, and the factor 1.5 is employed for the reason of potential fluctuations in the background concentrations as a result of lithological variances. However, several researchers (Sahu and Bhosale, 1991; Barreiro, 1991; Subramanian and Mohanachandran, 1990) used the earlier formula depending on local background values and on the less than 63 to 65 micrometer portion.

The Geo-accumulation indices, classes, and pollution intensity are shown in Table (3). In this study, Igeo has been estimated using three background values: first, the local value, which is reported in (Al-Bassam &Yousif, 2014); second, the global shale values (Turekian & Wedepohl, 1961); and third, the average Earth crust background values from (Taylor, 1964). The results show that the study area is unpolluted by (Fe, Mn, V, Cr, Zr), unpolluted to moderately polluted by (Zn, Cu, Ni), moderately polluted by Co, and for Pb, moderately to strongly polluted when using local background data in the formula, but unpolluted to moderately polluted by using global data (Table 4).

4.4.2. Pollution Load Index (PLI)

This index is a good parameter to link the pollution grade of various sites (Adebowale, 2009). The metals used in this method are (Mn, Fe, V, Co, Cr, Ni, Zr, Cu, As, Zn, Sr, and Pb), and the background values used are the same as in Igeo. The formula is:

$$plI = n\sqrt{CF1 \times CF2 \times CF3 \times \ldots \times CFn} \quad (2)$$

CF1, CF2, CF3,…, CFn are the concentration factors for each heavy metal in the sample. CF = Contamination Factor, C Background value = background value of that metal, C metal = metal concentration in polluted sediments, n = number of, if PLI value is more than one (1), the site is polluted, whereas less than one (1) shows no pollution (Harikumar *et al.*, 2009).

The results of PLI (Table 5) were found to be mostly High (more than one) in Hilla city compared with all background data, and that mean pollution.

Table 3. Geo-accumulation indices, classes, and pollution intensity (Muller, 1979).

geo	Class	Pollution intensity
> 5	6	Very strong polluted
4 – 5	5	Strong to very strong
3 – 4	4	Strongly polluted
2 – 3	3	Moderately to strongly
1 – 2	2	Moderately polluted
0 – 1	1	Unpolluted to mod. polluted
0	0	Unpolluted

Table 4. Results of the -accumulation Index in Hilla City.

Metals	Igeo					
	Al-Bassam		**AV.CRUSTAL**		**AV.Shale**	
	Igeo		**Igeo**		**Igeo**	
Fe			-1.9	unpolluted	-2.1	
Mn			-1.5	unpolluted	-1.7	
Pb	2.3	Moderately t	0.6	unpolluted to Moderately polluted	0.8	Moderately polluted
Cu	0.6	Moderately polluted	-0.8		-1.1	
V	-1.3		-1.7		-2.3	
Cr	-1.4		0.0		-0.2	
Ni	-0.2		0.2	Moderately polluted	0.1	Moderately polluted
Cc			1.7	Moderately polluted	1.3	Moderately polluted
Zn	0.5	Moderately polluted	-0.3	un polluted	0.1	un polluted
As			-1.7	un polluted	1.2	
Zr			-0.6	un polluted	-0.7	un polluted
Sr			1.2	Moderately polluted	0.1	un polluted

Table 5. Results of PLI using three sources of background values.

Metals	F			PLI1	PLI2	PLI3
	CF1	CF2	CF3	Iraq	glbal	global
	Al-Bassam	AV.CRUSTAL	AV.Shale	Al-Bassam	AV.CRUSTAL	AV.Shale
Fe		0.391	0.347	1.40	1.06	1.08
Mn		0.517	0.469			
Pb	7.603	2.281	2.683			
Cu	2.531	0.836	0.684			
V	0.597	0.471	0.314			
Cr	0.552	1.460	1.314			
Ni	1.294	1.732	1.570			
Cc		4.883	3.711			
Zn	2.138	1.215	1.649			
As		0.467	3.376			
Zr		0.978	0.949			
Sr		3.547	1.608			

4.4.3. Enrichment Factor (EF)

It is a rather easy and straightforward method to compare pollution of various environmental media and evaluate the enrichment grade based on its basic formula (Benhaddya& Hadjel, 2013).

$$EF = (M/Fe)_{sample}/(M/Fe)_{background} \quad (3)$$

“M/Fe” sample is the percentage of metal and (Fe) concentration for the sample, and “M/Fe” Background is the percentage of metal and (Fe) concentration for the background. Two background values are used. Average Shale data from (Turekian & Wedepohl, 1961) and average crust background values from (Taylor, 1964). According to Zhang and Liu (2002), EF values from 0.5 to 1.5 specify that the metal is totally from crustal sources or natural activity, while EF values more than 1.5 propose that the sources are more likely to be anthropogenic. Table 6 shows Enrichment Factor values, levels, and categories. As in Table 7, for (Fe, Mn, V, Cu, and Zr).EF values suggest Minor Enrichment, (Cr, Ni, and Zn) are Moderate Enrichment, (Pb) is Moderately Severe Enrichment, and finally (Co) is Severe Enrichment.

Table 6. Enrichment factors values, levels, and categories (Muller, 1979).

Enrichment factor		
Level	**Value**	**Categorisation**
I	EF<1	No enrichment
II	EF = 1 – 3	Minor enrichment
III	EF = 3 – 5	Moderate enrichment
IV	EF = 5 – 10	Moderately severe enrichment
V	EF = 10 – 25	Severe enrichment
VI	EF = 25 – 50	Very severe enrichment
VII	EF>50	Extremely severe enrichment

Table 7. Results of Enrichment Factor in Hilla City.

Metal	**EF**			
	AV.CRUSTAL	**Enrichment category**	**AV.Shale**	**Enrichment category**
Fe	1.0	Minor	1.0	Minor
Mn	1.3	Minor	1.4	Minor
Pb	5.8	Moderately severe	7.7	Moderately severe
Cu	2.1	Minor	2.0	Minor
V	1.2	Minor	0.9	No Enrichment
Cr	3.7	Moderate	3.8	Moderate
Ni	4.4	Moderate	4.5	Moderate
Co	12.5	Severe	10.7	Severe
Zn	3.1	Moderate	4.8	Moderate
Zr	2.5	Minor	2.7	Minor
Sr	9.1	Moderately severe	4.6	Moderate

4.4.4. Ecological Risk Factor (Eri)

To evaluate the toxicity of specific metals to humans with varying degrees of harmfulness. Håkanson (1980) established the following toxic-response factors for different metals: Zinc (Zn) is assigned a value of 1, Lead (Pb) has a value of 5, Copper (Cu) is also rated at 5, Nickel (Ni) is rated at 5, and Chromium (Cr) is given a value of 2. The formula for calculating Eri is detailed below.

$$Er_i = T_i * (C_n / C_{ref}) \quad (4)$$

Five pollution categories are proposed: Low (less than 40), Moderate (Er_i = 40 to 80), Significant (Er_i = 80 to 160), High (Er_i = 160 to 320), and Very High (more than 320). Background data of (Al-Bassam & Yousif,1914) are used as $C_{ref.}$ The results for the metals are all Low; Pb shows the highest value and is near being in the Moderate category (Table 8).

Table 8. Results of Eri for some metals in Hilla City.

Metal	Cn Hilla City Mean mg/kg	Cref 1 Iraq Al-Bassam mg/kg	T*i*	Er_i Iraq Al-Bassam	category
Pb	46	6	5	38	low
Cu	38	16	5	12	low
Cr	131	238	2	1	low
Ni	118	91	5	6	low
Zn	115	54	1	2	low

Potential Ecological Risk (RI) is the summation of the Eri values for metals in a specified sample (Soliman *et al.*, 2015). The categories of RI are categorized by (Hakanson, 1980) as: Low (RI less than 150), Moderate (RI = 150 to 300), Considerable (RI = 300 to 600), and High (RI more than 600). Thus, the results of RI are low for all stations in Hilla city, as shown in Table 9.

Table 9. Results of RI for some metals in Hilla City.

sample	Metals					Er_i					RI	Category
	Pb	Cu	Cr	Ni	Zn	Pb	Cu	Cr	Ni	Zn		
S1	100	37	64	108	149	83	12	1	6	3	104	low
S2	88	42	0	86	121	73	13	0	5	2	93	low
S3	72	25	144	140	149	60	8	1	8	3	80	low
S4	49	77	167	125	137	41	24	1	7	3	76	low
S5	38	47	134	111	115	32	15	1	6	2	56	low
S6	19	35	282	115	95	16	11	2	6	2	37	low
S7	20	19	57	119	105	17	6	0	7	2	32	low
S8	25	30	118	108	109	21	9	1	6	2	39	low
S9	20	27	171	117	71	17	8	1	6	1	34	low
S10	42	29	144	124	142	35	9	1	7	3	55	low
S11	31	62	0	119	87	26	19	0	7	2	53	low
S12	49	26	427	131	87	41	8	4	7	2	61	low
S13	40	32	0	128	134	33	10	0	7	2	53	low
Ti	5	2	5	1	/	/	/	/	/	/	/	/

4.4.5. Pollution Index (PI)

To evaluate the pollution grade of the heavy metals, PI for some metals was determined and introduced as the ratio of metal concentration to the background value of the identical metal via the formula (Chen *et al*., 2005):

$$PI = C_n / C_{ref} \quad (5)$$

Where Cn is the metal concentration, and Cref is the background concentration for the same metal n, as per Shi and Wang (2013): unpolluted (PI less than 1), low pollution (PI = 1 to 2), moderate pollution (PI = 2 to 3), and high pollution (PI more than 3). The results show high pollution in Pb and Co, moderate pollution in Cu and Zn, and low pollution in Ni and Cr when using local background values (Table 10).

Table 10. Results of PI for some metals in Hilla City.

Metals	PI					
	PI 1	Pollution category	PI 2	Pollution category	PI 3	Pollution category
	Al-Bassam		Av. CRUSTAL		Igeo	
Fe			0.391	Un polluted	0.347	un polluted
Mn			0.517	Un polluted	0.469	un polluted
Pb	6.516	High pollution	2.281	Moderate pollution	2.683	Moderate pollution
Cu	2.090	Moderate pollution	0.836	Un polluted	0.684	un polluted
V	0.558	Un polluted	0.471	Un polluted	0.314	un polluted
Cr			1.460	Un polluted	1.314	Low pollution
Ni	1.190	Low pollution	1.732	Un polluted Moderately polluted	1.570	Low pollution
Co			4.883	High pollution	3.711	High pollution
Zn	2.062	Moderate pollution	1.215	Low pollution	1.649	Low pollution
Zr			0.978	Un polluted	0.949	Un polluted
Sr			3.547	High pollution	1.608	Low pollution

5. Discussion

The findings of this reconnaissance analysis of some heavy metals in road dust of Hilla City, Iraq, have shed light on the concentration and spatial distribution of the analysed heavy metals and their possible environmental impact and health effects. The study discovered significant variation in the concentrations of a number of heavy metals, which has consequences for the management of urban pollution and public health.

5.1. Heavy Metal Concentrations and Sources:

Lead (Pb) and mercury (Hg) have high variability Coefficients, indicating significant variation in concentrations between sampling sites. Many factors, like local environmental conditions, industrial activity, and traffic density, may be related to these ranges. The close correlation between manganese (Mn) and iron (Fe) suggested a common source, most likely natural dust or geology. On the other hand, the moderate correlation between lead (Pb) and zinc (Zn) shows that they come from the same human sources, such as industrial discharge and vehicle emissions. The Cluster Analysis distinguished two groups of heavy metals according to their source.

The identification of copper (Cu) as primarily anthropogenic highlights the impact of motor traffic and urbanization on the composition of dust. Cu is often associated with tire wear and brake linings (Kumar et al., 2013; Bilos *et al.*, 2001), emphasizing the need for focused actions in high-traffic areas to lessen its release into the environment.

5.2. Spatial Distribution Patterns.

Pb and Cu levels in road dust samples are higher in areas with high traffic, particularly those close to gas stations and major roads, according to the geographical distribution analysis using ArcGIS. This result is in line with earlier studies (Pan *et al.*, 2017; Bilos *et al.*, 2001), which connected increased levels of heavy metals in urban dust to vehicle emissions. The elevated Fe and Mn concentrations close to important streets indicate that the composition of street dust is significantly influenced by urban infrastructure.

5.3. Environmental Pollution Indices.

While some metals are still at natural levels, Pb is a major pollution problem, according to the geo-accumulation index (Igeo) data. The fact that Pb is rated as moderately to severely polluted emphasizes how urgently Hilla City needs to implement pollution control measures. The results suggest that in order to effectively address these sources of pollution, local regulations pertaining to industrial operations and vehicle emissions should be reviewed.

5.4. Public Health Implications.

A serious public health concern is the presence of heavy metals in road dust. It is particularly for vulnerable populations such as children and the elderly. Chronic exposure to metals like lead can result in serious health issues, such as brain damage and delays in children's development. Campaigns to raise community awareness of the risks associated with dust pollution are therefore essential.

6. Conclusions and Recommendations

The present preliminary investigation on the road dust pollution in Hilla City (Iraq) has provided useful information with respect to the geoenvironmental impact of heavy metals from urban dust. Heavy metal contents varied greatly, which indicated the impact of natural and anthropogenic sources in 13 street dust samples collected and analyzed. The results indicate that Fe, Mn, V, Cr, and Zr still stay fairly harmless, while Pb and Cu would have moderate to severe pollution potential. The high variation coefficients of Pb and Hg show that the contribution to LEI from human activities is very large. Through correlation analysis and cluster analysis, the different sources of these metals were identified, among which Cu was mainly derived from anthropogenic sources. High concentrations of Pb and Cu are localised in the high-traffic sites as indicated by their spatial distribution patterns, thus necessitating targeted pollution control strategies. Pollution Load Index and Geo-Accumulation Index showed an unstable status of the pollution among metals, with lead being the most environmentally harmful. Finally, these results highlight the urgent need for protective and regulatory measures to control heavy metal pollution in Hilla City. Adopting appropriate policies to minimize vehicle and industry discharges will be essential for the protection of human health and environmental quality. Long-term monitoring of road dust is also needed in the future to investigate temporal fluctuations and the effectiveness of

implemented mitigation measures. In addition, if it is also possible to extend such a study to nearby areas, a proper level of regional pollution for the whole area can be obtained. Future investigations should also examine previously industrial sites that once housed metal materials to assess potential heavy metal contamination risks in the adjacent environment. Such locations contribute to metal accumulation issues within the surrounding soil and road dust, thereby necessitating targeted monitoring and remediation initiatives to safeguard environmental health. Accurate assessment and management practices for these sites are essential for reducing contamination impacts. Subsequent research should focus on more comprehensive and specific surveys that lead to the formulation of a long-term monitoring and evaluation strategy to tackle the enduring challenges posed by urban pollution.

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