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CONCENTRATION OF HEAVY METALS IN SOILS ALONG THREE MAJOR ROADS OF SULAIMANI, NORTHEAST IRAQ

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Abstract: Heavy metal contamination of agricultural soils resulting from vehicle emissions is a cause of serious concern due to the potential health impacts of transferring to food chain. In this study, heavy metal concentration of roadside soils along three major roads connecting the city of Sulaimani to surrounding cities were determined. Twenty soil samples from each side of three roads were collected at 1 m, 15 m, 25 m and 50 m distances from road edges. The heavy metals of Cr, Co, Pb, Cd and Ni were analyzed by acid digestion. Heavy metal pollution of roadside soils was assessed using three different environmental indices; enrichment factor (EF), contaminant factor (CF) and contamination degree (CD). Heavy metals concentrations of roadside soils were significantly different (P<0.01) among three major roads and usually decreased with increased distance from the roads. The highest concentrations were 268.56, 9.56, 134.16, 3.99 and 179.20 mg kg^{-1} for Cr, Co, Pb, Cd and Ni, respectively. The results showed that mean concentrations of all heavy metals determined were significantly higher than the global background values of heavy metals. The order of heavy metal contamination based on CF values in Arbat road was Cr>Ni>Pb>Cd>Co, in Kirkuk road Ni>Cr>Cd>Pb>Co, and in Mergapan road Pb>Ni>Cr>Cd>Co. Significant positive correlations between Ni and Co in Arbat (r=089) and Kirkuk (r=0.58) roads, Ni and Pb in Mergapan road (r=0.70), and Cd and Pb in Kirkuk road (r=0.76) revealed their common source in the studied environments. The roadside soils in the region are being extensively used for agricultural production. Therefore, the increased concentration of Cr, Pb, Cd and Ni in roadside soils should be carefully monitored and necessary precautions should be taken to prevent further accumulation in roadside soils.

Keywords: Cadmium, lead, nickel, chromium, cobalt, pollution, roadside soil

1. INTRODUCTION

The resistance of bio- and termo degradable nature of heavy metals cause to accumulation in soils at toxic levels due to the long-term addition (Bohn et al., 1985). Anthropogenic contribution of heavy metals from road traffic emissions has attracted the attentions of researchers due to their long-term accumulation especially in soils of agricultural fields located on roadsides. The studies conducted in various countries demonstrated that the concentration of heavy metals such as lead, cadmium, copper, zinc and chromium in roadside soils may reach to potentially toxic concentrations (Folkeson et al., 2009; Kicińska, 2016; De Silva et al., 2016; Najmeddin et al., 2017; Pan et al., 2018; Sürücü et al., 2018). The metal content in fuel, such as lead was markedly decreased in the world after the regulations on the use of leaded fuel which reduced the emission from a single vehicle. However, this effect was masked by the increasing traffic which caused to higher levels of heavy metal emissions in the roadside environment (Monks et al., 2009). Moreover, the previously deposited heavy metals remain a major problem of the roadside environments. The increased heavy metal concentration in agricultural soils resulting from vehicle emissions is a cause of serious concern due to the potential health impacts of transferring to food chain. The heavy metal transfer to human body through the soil-crop system has been considered as the predominant pathway of human exposure to heavy metals (Liu et al., 2013).

Total road network in Iraq, including primary, secondary and all other paved roads was reported as 59.623 km in 2013, and 14.840 km of all paved road network was in the northern region of the country. The current road density for the northern region is much lower (approximately 0.1 km km^{-2}) compared to some of the highly crowded cities of the world. For example, the road density in Barcelona is 7.4, in Beijing 4.7, in Mexico City 3.4 and in New Delhi (1.5 $kmkm^{-2}$). Lower road density in a region may reduce overall traffic-related air pollution, though low density means more vehicles travelling on existing roads, and potentially leading to greater pollution around the roads (Su et al., 2015). Sulaimani, the most crowded and sprawled city in the semi-autonomous area of northeast Iraq is the region’s cultural capital. The number of motor vehicles in Sulaimani Governorate (Sulaimani Identification Numbering) has increased rapidly from 32.468 in 1999 to 373.044 at the end of 2016, in addition to 64.614 vehicles registered with information cards and 10.921 motorcycles (Sulaimani Statistical Office, 2014). The increased number of vehicles, low road-density and cheap fuel in Sulaimani may bring concerns on environmental pollution, because vehicle emissions resulted from combustion of fuel, engine oil, brake wear and vehicular exhaust catalysts contain significant amount of hazardous metals (Winther & Slento, 2010; Hjortenkrans et al., 2007) which mostly accumulate in surrounding roadside soils (De Silva et al., 2016).

The dispersal range of metals depending on rain, water, gravity, topography, solubility of metals, physical and chemical properties of soils (Wong et al., 2006; Irmak et al., 2007; Saraçoğlu et al., 2013) ranges from 100 to 200 m from roadsides, although the majority are deposited within 20m of the road edge (Dan-Badjo et al., 2008). Heavy metals are reported to transport as far as 10 m across the edges of roadside area depending on type of road, degree of slope, spray and runoff water of road (Golwer, 1991). The concentration of heavy metals in the roadside soils usually decreases with the increasing distance from the road (Warren & Birch, 1987; Akbar et al., 2006).

Heavy metals enrichment in roadside soils from traffic activities is an important cause of land degradation in roadside farmland ecosystems. Therefore, studies on heavy metal pollution in urban soils, urban road dusts and agricultural soils are well documented in several countries all around the world. However, due to the long-lasting wars and conflicts in Iraq, little attention has been focused and research has been conducted to investigate heavy metal concentrations of roadside soils in Iraq (Al-Obaidy & Al-Mashhadi, 2013; Salah et al., 2013; Hamad et al., 2014). Rapid increase in the use of vehicles for day to day transportation along with lack of emission standards raised serious concern about pollution from vehicle emission in Iraq. This study focused on the heavy metal concentrations and their contamination levels in roadside soils on major roads connecting Sulaimani city to Arbat, Kirkuk and Mergapan cities. The concentrations and contamination levels of heavy metals determined in three different roads have been compared and spatial distributions were also discussed.

2. MATERIALS AND METHODS

2.1. Study Area

The study was conducted on three sections at main roads connecting Sulaimani city to Arbat, Kirkukand Mergapan cities (Fig. 1). The city of Sulaimani is located at 35º 33ˈ N and 45º 26ˈ E on the edges of wide the Zagros Mountain valley of northeastern Iraq with an altitude of about 860 m above sea level. The distance of section studied on Sulaimani - Kirkuk (Tasluja) road was 10 km with 0.76 % slope, 7 km on Sulaimani- Arbat road with 0.82 % slope, and 10 km on Sulaimani-Mergapan road with 0.46 % slope. Both sides of roads are used for agricultural production.

Soils in the region formed over carbonate and mixed clastic and carbonate parent materials (Karim et al., 2008). The soils in the Sulaimani region are classified as Vertic Kastanozems, Vertic Calcisols, Rendzic Leptosols, Leptic Fluvisol sand Skeletic Fluvisols (FAO, 2003). The climate of study area is semi-arid, long term annual average temperature is 18.5ºC and annual average precipitation is 600 mm.

2.2. Soil Sampling

A total of 120 topsoil samples from the depth of 0-15 cm were collected from the road edge on both sites of three major roads connecting city of Sulaimani to the Arbat, Kirkuk and Mergapan cities (Fig. 1).

The sampling distances to the road edges were designated as 1, 15, 25 and 50 m distances. Soil samples were dried at room temperature, gently ground and passed through 2 mm sieve to remove roots and rocks and then stored in plastic bags for subsequent analyses.

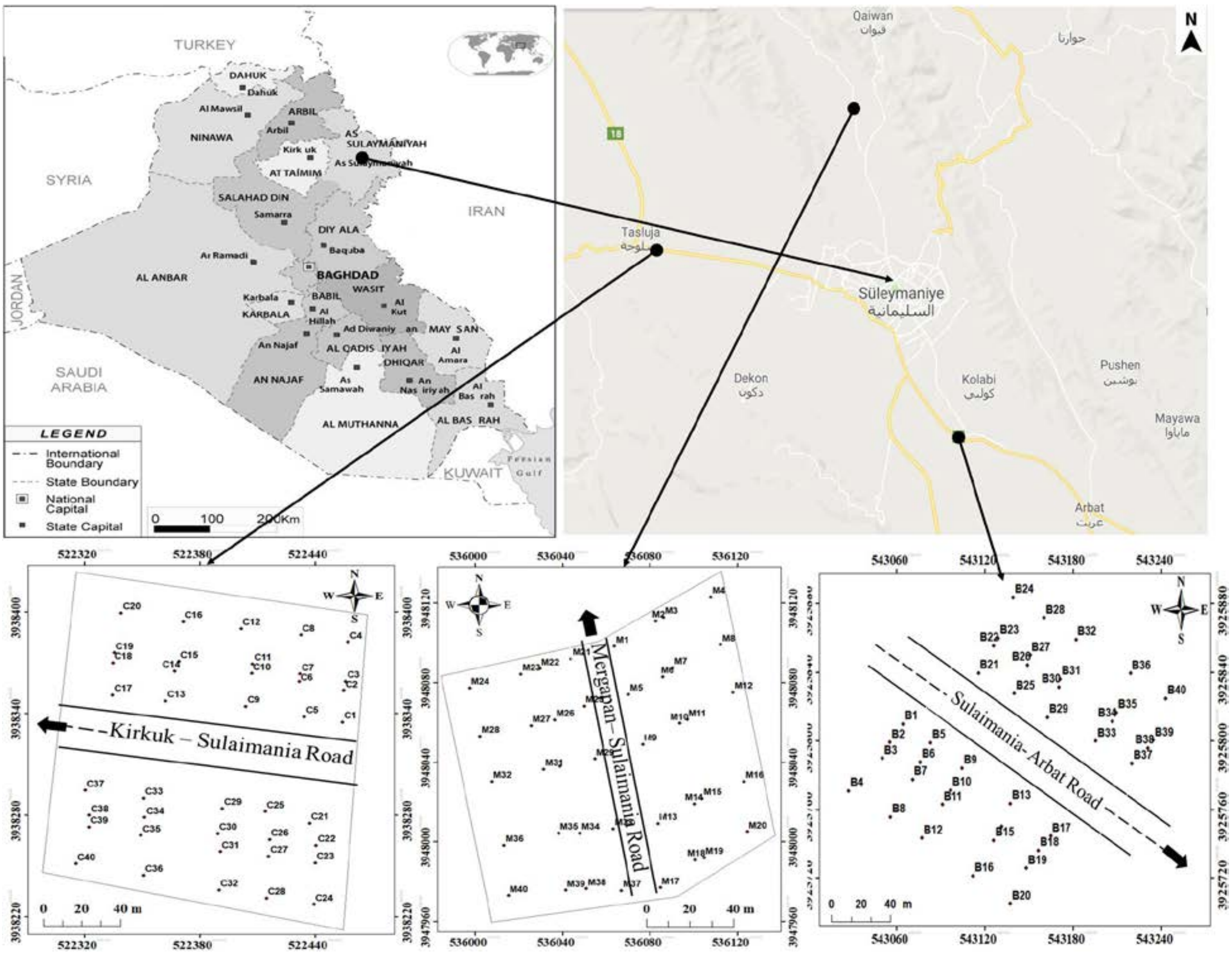

Figure 1. Location of soil sampling on the edges of Sulaimani-Kirkuk, Mergapan and Arbat roads.

Approximately 1.0 g of each soil sample was digested with aqua-reggia mixture (HNO_3:HCl mixture, 3:1 v/v) by means of microwave oven (MARS 6, Microwave Accelerated Reaction System, CEM Analytical) for the determination of pseudo-total concentration of heavy metals. For analysis, selected the temperature on (200) °C ramp time of 25 minutes, 30 minutes, Pressure which selected is 800 bar and microwave power was 1030-1800 for ashing and 15 minutes for cooling. After this time the vessel taken out and filtered through Whatman No. 40 filter paper and diluted to 50 ml, then the pseudo-total concentrations of Cr, Co, Pb, Cd and Ni in the digested samples were determined by using Atomic Absorption Spectrometer Perkin almer 8800.

2.3. Evaluation of Heavy Metal Pollution in Soils

Standards for the permissible concentrations of heavy metals in soils vary according to regions and countries. However, there is no common consensus on hazard levels of heavy metals in soils. The hazardousness of a particular heavy metal is assessed based on the impact on biological objects in soil and soil solutions (Vodyanitskii, 2016). Therefore, permissible limits recommended organizations and individual countries significantly differ from each other (Table 1).

2.3.1. Enrichment Factor

Enrichment factor (EF) is used to differentiate the metals originating from anthropogenic activities those from natural procedure, and to investigate the extend of anthropogenic influence (Lu et al., 2014). The degree of anthropogenic impact on heavy metal pollution is assessed based on the normalization of tested metals against reference metals. In this study, Fe is used as the reference metal which is one of the most abundant element of the earth crust. The EF for each of heavy metals analyzed in this study was calculated as fallow;

$$EF = \left(\frac{M(sample)}{Fe(sample)}\right) \div \left(\frac{M(crust)}{Fe(crust)}\right) \qquad \text{Eq.1}$$

Where $M_{(sample)}$ is the concentration (mg kg^{-1}) of target heavy metal in roadside soil, Fe $_{(sample)}$ is the concentration (mg kg^{-1}) of Fe in roadside soil, M (crust) is the concentration of target heavy metal in the earth crust and Fe (crust) is the concentration (mg kg^{-1}) of Fe in the earth crust. The EF values of all analyzed metals were calculated for each soil sample

Table 1. Permissible concentrations (mg kg^{-1}) of heavy metals in soils determined by several countries

	Cr	Co	Pb	Cd	Ni	Source
Netherlands	100	33	140	1.6	38	Crommentuijn et al., 2000
Romania, Residential	100	30	50	3.0	75	Mihali et al., 2013
Canada, Agricultural	64	40	70	1.4	45	CCME, 2018
Canada, Residential/Parkland	64	50	140	10	45	
Canada, Industrial	87	300	260	22	89	
India	n/a	n//a	500	0.7	150	Awashthi, 2000
China, pH > 7.5	250	n/a	350	0.6	60	CEPA, 1995
Concentration in soils	10-50	1-10	0.1-20	0.1-1.0	10-50	Fabis, 1987
Acceptable Values	100	50	100	3.0	50	
Maximum Values	100	50	100	3.0	50	
Average Crustal	100	10	14	0.1	20	Kabata-Pendias & Mukherjee, 2007
Worldwide Soils	42	6.9	25	1.1	18	

n/a: not available, Standards set for the Netherlands are valid for soils contain 10% organic matter and 25% clay

relative to the background value of corresponding elements in the earth crust. The EF values close to 1.0 refers to crustal origin and values higher than 10 indicates contribution of anthropogenic sources. Taylor (1964) defined seven EF classes to explain the degree of metal pollution (Table 2).

Table 2. Enrichment factor classes based on EF values

EF<1.0	No enrichment
EF=1.0 - <3.0	Minor enrichment
EF=3 - <5.0	Moderate enrichment
EF=5 - <10	Moderately severe enrichment
EF=10 - <25	Severe enrichment
EF=25 - <50	Very severe enrichment
EF≥50	Extremely severe enrichment

2.3.2. Contaminant Factor and Contamination Degree

Contamination factor is calculated as the ratio of each heavy metal concentration to background value that was worldwide soil concentration of the heavy metal (Eq. 2). Others have used background values as pre-industrial concentration of individual metal (Gowd et al., 2010) and concentration of elements in the Earth's crust (Loska et al., 2004).

$$CF = \left(\frac{M(sample)}{M(background)}\right) \quad \textbf{Eq.2.}$$

Where CF is the single element contaminant factor, M(sample) is the concentration of heavy metal analyzed, and the M (background) is the worldwide average concentration of heavy metal (Kabata-Pendias & Mukherjee, 2007). Total abundance of a particular heavy metal in an area of interest was assessed by a diagnostic tool named as "Degree of Contamination" (CD). The degree of contamination was calculated as the sum of individual CF values (Eq. 3) (Håkanson, 1980). We have calculated CD values for each sampling distance in each roadside, for each roadside in three roads and a separate CD value for each road (Table 3, 4 and 5).

$$CD = \sum_{i=1}^{i=n} CF \quad \textbf{Eq.3.}$$

The CF values were evaluated based on the classification of Håkanson (1980) in which CF ≤ 1shows low contamination; CF value of 1 < CF< 3 indicates moderate contamination; CF value of 3 ≤ CF< 6 is considerable contamination; and CF value ≥ 6 shows very high contamination of a heavy metal.

2.4. Data Analysis

The concentrations of heavy metals were used as the input data for spatial distribution maps. The software used for the spatial distribution maps of heavy metals was ArcGIS Version 10.1 developed by ESRI. The spatial interpolation of each heavy metals, based on data obtained for each sample site, was employed to estimate attribute values at unsampled sites within the sampled section of each road separately. Descriptive statistics (minimum, maximum, mean, standard deviation, standard error of mean, coefficient of variation and skewness), analysis of variances and correlation tests were carried out using SPSS 21.0 Software (SPSS Inc., Chicago, USA).

3. RESULTS AND DISCUSSION

Descriptive statistics of physico-chemical characteristics for roadside soils are given in Table 6. The pH values of soils ranged from 7.5 to 8.3 in Arbat road, from 7.0 to 8.2 in Kirkuk road and from 7.8 to 8.3 in Mergapan road. Soil reaction is an important attribute controlling the solubility of heavy metals in soil (Basta et al., 2005), all soils sampled around Sulaimani city were in neutral to slightly alkaline nature. Average pH value in all three locations was 8.0. The mean EC of soil samples indicated non-saline environment and EC was between 232 (Mergapan) to 774 µs cm^{-1} (Arbat).

Table 3. Assessment of anthropogenic contribution in Arbat roadside soils based on contaminant factor and contamination degree (mean value ± standard error of mean)

Road	Side	Distance (m)	Cr	Co	Pb	Cd	Ni
Contaminant Factor							
Arbat	North	1	4.7±0.4	0.7±0.1	2.9±0.1	1.5±0.5	3.4±0.4
		15	4.9±0.4	0.9±0.0	2.5±0.0	2.3±0.2	4.1±0.1
		25	4.5±0.7	0.8±0.1	2.8±0.1	1.7±0.6	3.6±0.4
		50	4.7±0.9	0.8±0.1	2.7±0.1	1.6±0.6	3.8±0.3
	South	1	5.2±0.4	0.9±0.2	2.6±0.2	1.7±0.45	3.9±0.5
		15	3.8±0.3	1.1±0.1	2.1±0.1	2.2±0.2	4.7±0.1
		25	4.7±0.4	0.9±0.2	2.4±0.3	1.7±0.2	3.9±0.5
		50	4.5±0.4	0.9±0.2	2.3±0.2	1.5±0.5	3.9±0.5
Contamination Degree							
Arbat	North	1	23.4	3.6	14.3	7.6	17.1
		15	24.3	4.4	12.7	11.7	20.2
		25	22.5	4.0	13.7	8.3	17.8
		50	23.3	4.0	13.3	7.8	19.2
		Contamination Degree North	93.5	15.9	54.0	35.3	74.2
	South	1	25.9	4.5	12.8	8.7	19.4
		15	19.0	5.7	10.6	10.9	23.6
		25	23.7	4.3	12.1	8.4	19.4
		50	22.6	4.4	11.6	7.7	19.5
		Contamination Degree South	91.1	19.0	47.1	35.7	82.0

Table 4. Assessment of anthropogenic contribution in Kirkuk roadside soils based on contaminant factor and contamination degree (mean value ± standard error of mean)

Road	Side	Distance (m)	Cr	Co	Pb	Cd	Ni
Contaminant Factor							
	North	1	4.0±0.5	1.1±0.1	1.8±0.0	2.9±0.3	6.6±2.2
		15	4.4±0.4	0.9±0.0	1.8±0.1	2.8±0.2	5.0±0.4
		25	4.9±0.6	1.1±0.1	1.7±0.1	2.5±0.3	7.3±1.7
		50	4.6±0.3	1.1±0.1	1.6±0.2	2.6±0.2	7.5±1.6
	South	1	6.4±0.9	1.2±0.1	2.0±0.1	3.5±0.3	10.0±1.0
		15	6.0±1.0	1.2±0.1	1.9±0.1	3.6±0.2	7.6±1.9
		25	5.4±1.4	1.2±0.0	1.8±0.1	3.2±0.4	8.5±2.0
		50	5.2±0.9	1.2±0.1	1.8±0.1	3.2±0.5	5.7±1.4
Contamination Degree							
Kirkuk	North	1	20.1	5.5	9.4	14.7	32.8
		15	21.9	4.6	9.2	14.1	25.1
		25	24.7	5.4	8.6	12.4	36.3
		50	23.2	5.3	7.8	13.0	37.6
		Contamination Degree North	89.9	20.8	34.7	54.1	131.7
	South	1	32.0	6.0	10.1	17.7	49.8
		15	30.0	6.0	9.5	18.0	38.2
		25	27.2	5.8	9.2	16.2	42.4
		50	25.8	5.9	8.9	15.9	28.5
		Contamination Degree South	115.0	23.7	37.8	67.9	158.9

Soil organic matter (SOM) is considered an important sink for a large fraction of metals of anthropogenic origin (Werkenthin et al., 2014), but SOM content in soils investigated was relatively low, indicating low potential for binding heavy metals in insoluble form and bioavailability of heavy metals (Basta et al., 2005). Calcium carbonate content of soils were high and ranged from 11.3% to 55.7% with the mean values of 23.6, 21.9 and 30.4% in Arbat, Kirkuk and Mergapan roads, respectively. High calcium carbonate of soils can be ascribed by the parent material of calcareous alluvium belongs to the Pleistocene age (Hussain et al., 1984) and low precipitation of the study area. The concentrations of soil total Cr, Co, Pb, Cd and Ni were significantly different (< 0.0001) among three different road side environments, while the effects of direction (except for Co), distance (except for Cd) and two and threeway interactions of factors were not statistically significant (Table 7). The mean total Cr, Co, Pb, Cd and Ni concentrations in the roadside soils and corresponding enrichment factor values at three different locations were presented in Table 8, 9 and 10.

Average concentrations of all the analyzed heavy metals in the roadside soils were higher than the corresponding values determined for the earth crust and average worldwide soils (Table 1), except for Co concentration was lower than earth crust and similar to worldwide soils.

Table 5. Assessment of anthropogenic contribution in Mergapan roadside soils based on contaminant factor and contamination degree (mean value ± standard error of mean)

Road	Side	Distance (m)	Cr	Co	Pb	Cd	Ni
Contaminant Factor							
Mergapan	North	1	2.6±0.7	1.0±0.1	5.7±1.1	3.3±0.1	3.9±0.6
		15	3.9±0.3	1.2±0.0	3.9±0.1	3.6±0.4	3.2±0.4
		25	3.3±0.8	1.0±0.1	5.2±1.1	2.9±0.2	3.9±0.5
		50	3.5±0.5	1.1±0.1	5.1±0.9	3.1±0.3	5.1±1.3
	South	1	3.3±0.6	1.2±0.1	5.4±1.0	3.3±0.2	4.4±1.4
		15	3.9±0.4	1.4±0.0	3.3±0.1	3.4±0.2	3.4±0.3
		25	3.6±0.5	1.2±0.1	5.0±1.0	2.4±0.2	4.4±0.6
		50	4.1±0.9	1.1±0.1	4.9±0.9	2.4±0.2	4.3±0.7
Contamination Degree							
Mergapan	North	1	12.8	5.2	28.3	16.3	19.6
		15	19.4	5.8	19.6	18.1	15.9
		25	16.6	5.2	26.1	14.4	19.3
		50	17.5	5.7	25.4	15.3	25.6
		Contamination Degree North	66.3	21.9	99.4	64.2	80.4
	South	1	16.6	5.8	26.8	16.5	22.2
		15	19.3	6.9	16.4	16.9	17.0
		25	18.1	5.8	25.0	12.2	21.9
		50	20.5	5.7	24.7	11.8	21.6
		Contamination Degree South	74.5	24.3	93.0	57.5	82.7

Table 6. Parameters for descriptive statistics of physico-chemical properties of soils

Soil Attributes	Unit	Minimum	Maximum	Mean	Standard Deviation	CV*	Skewness
Sulaimani-Arbat Road							
Clay	%	25.4	56.5	46.1	7.73	16.8	-1.02
Silt		20.8	42.4	31.7	4.38	13.8	-0.26
Sand		10.1	44.1	22.2	9.31	41.9	0.75
$CaCO_3$		15.2	27.9	23.6	3.20	13.6	-0.82
pH		7.5	8.3	8.0	0.14	1.7	-0.75
EC	µs cm^{-1}	353.0	774.0	583.05	106.74	18.3	-0.31
Org Matter	%	0.29	1.21	0.79	0.23	29.2	-0.31
Sulaimani-Kirkuk Road							
Clay	%	12.5	59.8	48.3	9.77	20.2	-2.02
Silt		8.4	38.7	28.2	7.09	25.1	-0.85
Sand		11.2	79.1	23.5	15.52	66.1	1.87
$CaCO_3$		11.3	35.9	21.9	5.40	24.6	0.24
pH		7.0	8.2	8.0	0.19	2.4	-3.57
EC	µs cm^{-1}	347.0	758.0	503.68	91.67	18.2	0.51
Org Matter	%	0.61	2.22	1.42	0.36	25.4	0.14
	Sulaimani-Mergapan Road						
Clay	%	23.5	56.1	43.7	7.95	18.2	-0.70
Silt		2.1	40.3	26.7	6.43	24.1	-1.26
Sand		13.0	72.9	29.7	12.26	41.3	1.45
$CaCO_3$		15.5	55.7	30.4	9.48	31.1	0.61
pH		7.8	8.3	8.0	0.11	1.4	0.39
EC	µs cm^{-1}	232.0	568.0	389.3	86.27	22.2	0.34
Org Matter	%	0.16	2.05	1.07	0.48	44.9	0.31

*CV: Coefficient of Variation

Table 7. Analysis of variances for heavy metal concentrations of roadside soils

Factors	Cr	Co	Pb	Cd	Ni
Road	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Direction	0.0624	0.0007	0.4198	0.3903	0.1577
Distance	0.9943	0.3060	0.0674	0.0090	0.6958
Road x Direction	0.1233	0.9343	0.5445	0.0158	0.4742
Road x Distance	0.7481	0.3764	0.1609	0.7438	0.4636
Direction x Distance	0.5274	0.2845	0.9764	0.8739	0.2464
Road x Direction x Distance	0.8648	0.9954	0.9999	0.9881	0.7563

Table 8. Mean heavy metal concentrations and enrichment factors for roadside surface soils of Sulaimani-Arbat road.

Arbat		South				North			
	Distance (m)	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
Cr mg kg-1	1	152.90	243.10	196.46	29.76	177.20	264.90	217.40	36.28
	15	137.60	244.20	203.78	35.76	124.40	193.20	159.18	26.64
	25	96.30	281.50	188.78	61.12	157.90	249.90	198.88	30.41
	50	82.30	300.60	196.12	77.63	135.90	220.00	189.78	32.75
Co mgkg-1	1	3.83	7.14	4.95	1.16	2.81	10.59	6.25	2.70
	15	4.98	6.71	6.03	0.60	7.18	9.12	7.87	0.66
	25	4.04	6.68	5.54	0.97	3.23	8.86	5.93	2.36
	50	3.77	6.84	5.49	1.14	3.03	9.34	6.14	2.56
Pb mg kg-1	1	64.60	80.20	71.30	5.99	48.00	75.90	64.08	9.43
	15	62.70	64.30	63.52	0.66	43.50	59.20	53.18	6.09
	25	60.50	79.30	68.72	6.48	41.90	74.40	60.50	12.87
	50	59.50	72.80	66.50	4.69	40.40	68.30	57.94	11.30
Cd mg kg-1	1	0.19	3.11	1.66	1.13	0.08	3.11	1.91	1.08
	15	2.27	3.23	2.57	0.36	1.96	3.07	2.41	0.38
	25	0.19	3.26	1.83	1.33	0.50	3.10	1.85	0.92
	50	0.11	3.43	1.71	1.23	0.19	3.00	1.69	1.14
Ni mg kg-1	1	41.40	81.30	61.38	14.03	51.30	91.50	69.92	16.18
	15	68.00	80.60	72.82	4.63	77.30	90.30	85.02	4.75
	25	44.40	83.20	63.98	13.36	53.00	90.80	69.84	16.53
	50	50.80	80.10	68.94	10.85	50.00	94.70	70.24	17.94
Enrichment Factor									
Cr	1	2.05	3.02	2.49	0.34	2.13	3.42	2.77	0.54
	15	2.13	4.41	3.01	0.76	1.84	2.52	2.24	0.31
	25	1.36	3.79	2.49	0.78	2.19	3.75	2.78	0.52
	50	1.35	4.05	2.76	0.94	1.70	2.97	2.62	0.47
Co	1	0.46	0.92	0.64	0.18	0.36	1.21	0.78	0.31
	15	0.77	1.18	0.89	0.15	1.01	1.24	1.11	0.08
	25	0.54	0.95	0.74	0.16	0.43	1.23	0.82	0.31
	50	0.50	1.09	0.80	0.19	0.39	1.27	0.84	0.34
Pb	1	4.74	8.83	6.58	1.32	4.23	6.27	5.39	0.84
	15	5.88	8.11	6.69	0.83	4.15	7.49	6.05	1.39
	25	5.20	8.76	6.61	1.20	3.93	8.07	5.77	1.50
	50	5.60	8.45	6.90	0.92	3.96	5.50	4.64	0.52
Cd	1	2.49	38.67	20.13	13.34	1.07	37.06	23.95	13.34
	15	31.10	42.88	37.59	4.88	29.06	41.82	33.85	4.54
	25	2.94	43.16	24.77	18.01	7.51	42.98	25.50	12.49
	50	1.48	42.65	23.62	15.37	2.58	40.87	23.82	16.45
Ni	1	2.57	4.58	3.87	0.68	3.30	5.74	4.42	0.94
	15	4.66	6.80	5.37	0.77	5.80	6.15	5.99	0.13
	25	2.99	5.89	4.32	1.15	3.65	6.29	4.85	1.05
	50	3.36	6.56	5.07	1.27	3.23	6.45	4.83	1.18

The mean concentration of total Cr of soil samples ranged from 139.16 to 241.48 mg kg^{-1} which are above the permissible upper limits of many countries (Table 1). The highest Cr concentration (268.56 mg Cr kg^{-1}) was obtained on the left side of Kirkuk road at 1 m distance, while the lowest (107.36 mg Cr kg^{-1}) was on the right side of Mergapan road at 1m (Table 10). When the minimum mean concentration of Cr obtained was compared with the levels in similar studies elsewhere, the concentration of total Cr was lower than the concentration of 182.1, 232.4 mg kg^{-1} recorded for Seoul City, Korea (Lee et al., 2005) and Kavala, Greece (Christoforidis and Stamatis, 2009) respectively, but it was higher than those reported for Hong Kong (Li et al., 2001), Shanghai, China (Shi et al., 2008) and Murcia City, Spain (Acosta et al., 2009), respectively (Table 11).

The Pb is released from motor-vehicle exhaust fumes (Gowd et al., 2010). The permissible limits for Pb in soils set by the countries are significantly differed from each other and ranged from 70 to 500 mg kg^{-1}. The Pb concentrations in Arbat and Mergapan roadside soils sometimes exceeded the permissible limits and were ranged from 53.18 to 71.30 mg kg^{-1}, from 39.14 to 50.66 mg kg^{-1} and from 82.00 to 141.58 mg kg^{-1} in Arbat, Kirkuk and Mergapan roads, respectively. The Pb content for surface soil on worldwide has been estimated to be 25 mg kg^{-1} and above this level is considered as an anthropogenic influence (Kabata-Pendias and Mukherjee, 2007). All Pb contents measured in the study area are significantly higher than the baseline global Pb content (25 mg kg^{-1}). The Pb concentrations in roadside soils of Sulaimani are similar to those reported for Duhok city, Iraq (88.28 mg kg^{-1}) (Yousif, 2016) residential (87.06 mg kg^{-1}), commercial (110.30 mg kg^{-1}) and industrial areas (129.99 mg kg^{-1}) of Baghdad city, Iraq, higher than those found in Fallujah (3.82 mg kg^{-1}) (Salah et al., 2013) and Kirkuk cities (21.73 and 13.25 mg kg^{-1}) (Hussain, 2016), and less than lower than that in Hilla city (430.8 mg kg^{-1}) (Al-Fatlawi and Al-Alwani, 2012), Iraq (Table 12). The Pb contents reported by Khorshid and Bruhn (2016) for roadside soils inside

Table 9. Mean heavy metal concentrations and enrichment factors for roadside surface soils of Sulaimani-Kirkuk road.

Kirkuk		South				North			
	Distance (m)	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
Cr mg kg^{-1}	1	113.90	235.30	168.78	44.80	185.50	381.40	268.56	72.74
	15	134.60	221.10	184.34	31.09	161.60	383.60	252.06	82.80
	25	159.00	288.10	207.28	51.82	104.60	448.90	228.60	119.55
	50	167.70	228.90	195.12	24.41	130.50	348.50	216.70	74.28
Co $mgkg^{-1}$	1	5.93	10.21	7.57	1.75	6.25	9.73	8.28	1.26
	15	5.51	7.07	6.30	0.61	6.62	9.06	8.28	0.93
	25	5.14	9.27	7.50	1.45	7.39	8.80	7.96	0.59
	50	5.71	9.16	7.34	1.22	6.66	8.86	8.11	0.78
Pb mg kg^{-1}	1	42.10	47.80	45.18	1.86	38.60	59.50	50.66	7.29
	15	40.20	52.70	45.96	4.48	44.00	52.90	47.70	3.26
	25	38.50	48.00	43.08	3.13	39.10	53.50	45.98	6.16
	50	19.40	48.70	39.14	10.35	36.60	52.20	44.72	6.06
Cd mg kg^{-1}	1	2.75	4.33	3.23	0.61	2.90	4.99	3.90	0.69
	15	2.76	3.89	3.10	0.40	3.37	4.57	3.95	0.50
	25	1.40	3.18	2.73	0.68	2.72	4.84	3.57	0.92
	50	2.09	3.34	2.86	0.45	2.50	4.92	3.50	1.11
Ni mg kg^{-1}	1	38.40	240.90	118.10	78.65	129.10	240.30	179.20	36.40
	15	71.20	117.10	90.20	15.00	69.40	259.80	137.62	68.64
	25	63.60	206.10	130.70	61.05	64.20	243.60	152.68	72.71
	50	74.10	202.90	135.26	55.80	48.60	169.20	102.44	49.89
Enrichment Factor									
Cr	1	1.50	3.09	2.40	0.59	2.81	4.49	3.59	0.74
	15	1.78	2.75	2.39	0.37	1.75	3.74	2.66	0.73
	25	2.03	3.18	2.61	0.49	1.42	6.05	3.07	1.69
	50	2.24	2.56	2.41	0.12	1.55	5.48	2.89	1.36
Co	1	0.64	0.93	0.82	0.10	0.72	1.05	0.89	0.12
	15	0.66	1.17	0.96	0.20	0.90	1.17	1.05	0.10
	25	0.58	1.29	0.94	0.27	0.75	1.26	1.05	0.18
	50	1.00	1.34	1.12	0.12	0.77	1.17	0.91	0.15
Pb	1	3.72	4.72	4.26	0.35	3.24	4.22	3.67	0.43
	15	3.34	4.95	3.95	0.54	3.79	5.08	4.31	0.48
	25	1.94	5.31	3.48	1.09	3.62	4.44	4.07	0.35
	50	4.00	6.04	4.90	0.67	8.17	18.95	12.43	4.01
Cd	1	36.20	57.87	46.28	9.34	42.07	59.11	52.46	6.09
	15	34.96	45.36	40.13	3.90	33.54	54.10	42.83	7.97
	25	15.82	49.37	35.54	11.02	36.95	55.21	46.20	7.56
	50	29.32	50.97	35.76	7.84	27.98	57.67	44.36	11.58
Ni	1	3.21	18.50	8.45	5.90	9.77	17.43	12.19	2.81
	15	5.10	6.62	5.80	0.49	4.11	12.67	7.18	3.11
	25	4.07	13.45	8.21	3.65	3.66	16.40	10.55	5.59
	50	3.78	14.19	8.84	4.36	2.89	12.01	6.99	4.14

Table 10. Mean heavy metal concentrations and enrichment factors for roadside surface soils of Sulaimani-Mergapan road.

Mergapan		South				North			
	Distance (m)	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
Cr mg kg^{-1}	1	44.10	174.00	107.36	55.96	40.70	182.70	139.36	51.00
	15	120.70	197.40	162.86	24.93	121.60	216.80	161.88	32.16
	25	64.40	253.50	139.14	71.18	86.00	205.00	152.18	45.81
	50	82.90	191.80	147.28	40.85	75.20	273.20	172.00	72.70
Co mgkg^{-1}	1	5.86	9.08	7.22	1.11	6.23	9.32	8.05	1.17
	15	7.49	8.81	7.94	0.48	9.25	9.80	9.56	0.18
	25	6.18	8.72	7.20	1.07	6.53	9.42	7.98	1.26
	50	6.99	9.39	7.90	0.98	6.44	9.51	7.91	1.30
Pb mg kg^{-1}	1	91.00	245.00	141.58	56.38	84.60	204.60	134.16	49.43
	15	92.70	105.60	98.06	4.48	77.60	86.00	82.00	3.01
	25	89.40	234.80	130.58	54.10	74.70	196.20	125.22	49.17
	50	92.10	214.30	126.92	44.89	82.70	189.10	123.70	43.01
Cd mg kg^{-1}	1	3.18	4.04	3.59	0.30	3.05	4.29	3.64	0.41
	15	3.01	5.01	3.99	0.83	3.22	4.26	3.73	0.37
	25	2.32	3.92	3.17	0.52	2.27	3.37	2.69	0.43
	50	2.73	4.48	3.37	0.62	1.79	3.34	2.59	0.51
Ni mg kg^{-1}	1	3.05	4.29	3.64	0.41	37.20	179.30	79.80	51.52
	15	3.22	4.26	3.73	0.37	48.30	69.40	61.32	9.27
	25	2.27	3.37	2.69	0.43	48.50	103.10	78.70	23.22
	50	1.79	3.34	2.59	0.51	45.90	108.00	77.86	24.62
Enrichment Factor									
Cr	1	0.59	2.25	1.34	0.71	0.58	4.01	2.11	1.12
	15	1.89	3.03	2.27	0.43	1.43	3.98	2.27	0.93
	25	0.78	2.99	1.62	0.82	0.86	4.14	2.32	1.35
	50	0.82	2.50	1.63	0.61	0.78	5.46	2.78	1.95
Co	1	0.77	1.17	0.91	0.15	0.82	2.05	1.21	0.45
	15	0.87	1.55	1.13	0.24	0.94	2.42	1.35	0.55
	25	0.61	1.03	0.85	0.15	0.66	1.93	1.19	0.60
	50	0.68	1.23	0.87	0.23	0.64	2.03	1.20	0.62
Pb	1	7.84	13.84	10.00	2.40	5.44	14.40	8.25	3.18
	15	7.52	22.72	11.35	5.85	7.27	14.16	11.28	2.26
	25	7.58	14.48	9.51	2.54	7.20	14.01	11.52	2.36
	50	8.61	18.22	13.24	3.26	5.44	14.40	8.25	3.18
Cd	1	36.39	52.89	45.17	5.47	31.03	83.24	54.46	17.21
	15	36.00	96.90	58.89	24.11	31.59	96.47	53.54	23.51
	25	22.96	53.10	38.03	9.60	22.94	67.98	40.17	20.37
	50	25.82	58.49	37.17	11.86	17.71	72.68	39.32	20.74
Ni	1	3.45	5.88	4.35	0.87	3.11	9.12	5.18	2.09
	15	2.88	4.57	3.91	0.68	3.40	5.97	4.11	0.95
	25	2.89	5.23	4.07	0.86	4.27	5.45	5.00	0.40
	50	2.83	7.72	4.70	1.87	3.98	5.60	5.00	0.56

the Sulaimani city (78.9, 59.4 and 71.1 mg kg^{-1}) were similar those obtained in Arbat and Kirkuk roads. Despite the global concerns and constrains on using Pb as a fuel additive, the Pb is being still used as a fuel additive in Iraq (Khorshid & Bruhn, 2016). Therefore, the Pb concentrations of roadside soils in most of Iraqi cities were higher than the global baseline level, suggesting that considerable amount of Pb emitted from vehicles deposited on the vicinity of roads in Iraq.

The mean concentration of Co was 5.50 and 6.55 mg kg^{-1} in NE and SW of Arbat road, 7.18 and 8.16 mg kg^{-1} in N and S of Kirkuk road and 7.60 and 8.37 mg kg^{-1} in E and W of Mergapan road (Table 8, 9 and 10). All Co concentrations of roadside soils obtained were lower than the permissible limits set by the different countries (Table 1), while they were higher than the global background value of Co which was 6.9 mg kg^{-1} (Table 1) (Kabata-Pendias & Mukherjee, 2007). The mean Co concentrations of roadside soils in this study were lower than those reported for roadside soils in Duhok (40.54 mg kg^{-1}) and Hilla (42.25 mg kg^{-1}g) cities, Iraq (Table 12) (Yousif, 2016; Al-Fatlawi and Al-Alwani, 2012).

The Cd concentrations of roadside soils ranged from 1.66 (SW Arbat road) to 3.99 mg kg^{-1} (NE Mergapan road) which were mostly higher than the maximum permissible levels. The permissible concentration of Cd in Canada for agricultural soil is 1.4 mg kg^{-1}, in India 0.7 mg kg^{-1} and in China 0.6 mg kg^{-1}.

The mean Cd concentrations on both edges of Kirkuk and Mergapan roads were almost exceeded the 3.0 mg kg^{-1} that implies a severe Cd pollution of agricultural soils around these roads. The natural Cd concentration in soils ranges from 0.1 to 1.0 mg kg^{-1} (Fabis, 1987), and the global reference value is 1.1 mg kg^{-1} (Kabata-Pendias and Mukherjee, 2007) thus the increased Cd concentration of soils probably resulted from the lubricating oil and/or old tires of vehicles used on the roads (Alsbou & Al-Khashman, 2018). The Cd concentrations of roadside soils in this study were found to be close to those obtained in roadside soils of Duhok (3.42 mg kg^{-1}) (Yousif, 2016) and Hilla (2.60 mg kg^{-1}) (Al-Fatlawi and Al-Alwani, 2012) cities around the Iraq (Table 12). In contrast to our findings for the Cd contents of roadside soils around the city of Sulaimani, Khorshid and Bruhn (2016) reported very low Cd contents for the roadside soils with low traffic (0.33 mg kg^{-1}), semi-heavy traffic (0.24 mg kg^{-1}) and heavy traffic (0.54 mg kg^{-1}) inside the Sulaimani city.

The permissible limit of Ni in soils ranges from 38 (Netherland) to 150 mg kg^{-1} (India) depending on the criteria considered by the particular country (Table 1). The mean Ni concentration of soils for all three roads was between 68.78 (SW, Arbat road) and 142.99 mg kg^{-1} (S, Kirkuk road) (Table 8 and 9) which were above the maximum permissible limits set by most of the countries (Table 1). The Ni concentrations of roadside soils in all three roads were lower than the global background value Ni which was 18 mg kg^{-1} (Kabata-Pendias & Mukherjee, 2007). The Ni concentrations of roadside soils obtained in this study are in accordance with those found in Duhok, Hilla and Baghdad (residential and commercial areas) cities of Iraq, and higher compared to those reported in previous studies conducted on heavy metal pollution of soils in Iraq (Table 12).

3.1. Enrichment Factor, Contaminant Factor and Contamination Degree of Heavy Metals

The EF average for all metals follow the decreasing order as: Co (0.8-0.9) > Cr (2.6, 2.7) > Ni (4.7-5.0) >Pb (5.8-6.7) > Cd (26.5-26.8) in north east and south west side of Arbat road. In Kirkuk road the decreasing order of EF values were Co (1.0-1.0) > Cr (2.5, 3.1) > Ni (7.8-9.2) >Pb (4.1-4.2) > Cd (39.4-46.5) in north and south sides. The EF values in Mergapan roadside soils were decreased in the order of Co (1.0-1.2) > Cr (1.7, 2.4) > Ni (4.3-4.8) >Pb (10.8-11.1) > Cd (44.8-46.9) for east and west side of the road (Table 8, 9 and 10).

The mean EF values indicated no (EF < 1.0) and minor enrichments for Co (EF=1 < 3.0), while the mean EF values for Cr also suggested minor enrichment, except the south of Kirkuk road that had mean EF values of 3.1. However, the mean EF values of Pb suggested moderate, moderately severe and severe enrichment of roadside soils with Pb. The EF for Ni also indicated moderate and moderately severe enrichment of roadside soils. The EF for Cd ranged from 20.1 to 58.9, which falls under the class of severe and extremely severe enrichment. Therefore, the source of Cd in roadside soils appears to be anthropogenic from the existing oil and tires of vehicles.

The order of heavy metal contamination based on CF values in Arbat road was Cr>Ni>Pb>Cd>Co, in Kirkuk road Ni>Cr>Cd>Pb>Co, and in Mergapan road Pb>Ni>Cr>Cd>Co. The CF values for Cr ranged from 2.6 (north, Mergapan at 1 m distance) to 6.4 (south, Kirkuk at 1m distance) indicating moderate to high contamination of roadside soils with Cr. The CD values had also similar trend and the highest degree of accumulation was occurred at 1 m distances (CD, 32.0) in the south side of Kirkuk Road and the lowest (CD, 12.8) was at 1 m distances in the north side of Mergapan roadside soils (Tables 4 and 5). The CD for Co contents revealed low to moderate contamination of roadside soils with Co. The CD value for Co was between 0.7 (north, Arbat at 1 distance) and 1.4 (south, Mergapan at 15 m distance). The highest CD value (24.3) was obtained for south side of Mergapan roads, while the lowest value was found on north side of Arbat road (Table 3 and 5). Based on CD values of Pb contents, roadside soils of Arbat and Kirkuk roads were moderately contaminated (1 < CF < 3) whereas both sides of Mergapan road were considerable contaminated (CF value of 3 ≤ CF < 6). The Arbat roadside soils were moderately contaminated by Cd (1 < CF < 3) while Kirkuk and Mergapan roads were moderately and considerably contained by Cd. The degree of contamination is the sum of CF values obtained for different sampling distance in a roadside, and CD values ranged from 35.3 in north side of Arbat road to 67.9 in south side of Kirkuk road (Tables 3 and 4). Both sides of three roads were moderately, considerably or highly contaminated by Ni. The CF value was between 3.2 (north side at 1 m distance Mergapan) and 10.0 (south side at 1 m distance Kirkuk road) (Tables 4 and 5).

3.2. Correlations Between Heavy Metal Contents of Roadside Soils

The concentrations of heavy metals in soils depend on composition of parent materials and lithology, soil forming processes and modes of contribution by anthropogenic sources (Li et al., 2008). The Pearson correlation was performed between heavy metal concentrations in roadside soils and the distances from the road (Table 11). The correlation analysis of heavy metals in roadside soils relevant to the traffic activities will contribute to clarify the homology of pollution source (Zhang et al., 2012). The correlation analysis of the heavy metals showed that Ni concentration of roadside soils had significant positive/negative correlations with Co, Cr, Pb and Cd contents in all three roadside soils. In contrast to our findings Hui et al., (2017) did not find any significant correlations with Pb, Cd, Cu and Zn contents in roadside soils along the Shenyang-Dalian Highway of Liaoning Province, China. Similar to Ni, the Pb and Co contents of roadside soils were significantly correlated with all heavy metals investigated in Arbat and Mergapan roads, while Pb content had only significant correlations with Cd in Kirkuk roadside soils.

The Cr contents were significantly correlated to Co, Pb and Ni contents in Arbat and Mergapan roads, in contrast there was no correlation between Cr and Cd in all three roadside soils. Since no other sources of pollution exist at the studied site, positive correlations or coexistence of heavy metals such as Pb & Cd (r= 0.76) in Kirkuk road Co & Cd in Arbat (r= 0.52) and Mergapan (r= 0.35) roads, Ni & Co in Arbat (r= 0.89) and Kirkuk (r= 0.58) roads can be logically explained by heavy metal emissions of vehicular used on these roads (Table 11). Spatial distribution maps of Cd and Pb for Kirkuk roadside soils supports the significant positive correlation obtained between Cd and Pb contents (Fig. 2 and 3). Similar to our findings on coexistence of heavy metals on roadside soils, Zhang et al., (2012) reported

Table11. Correlation analysis of the among heavy metals of three roadside soils in Iraq.

	Variables	Distance	Cr	Co	Pb	Cd	Ni
Arbat	Distance	**1**	-0.07	-0.03	-0.12	-0.10	0.00
	Cr		**1**	**-0.46****	**0.34***	-0.15	**-0.56****
	Co			**1**	**-0.86****	**0.52****	**0.89*****
	Pb				**1**	**-0.49****	**-0.86****
	Cd					**1**	**0.48****
	Ni						**1**
Kirkuk	Distance	**1**	-0.06	-0.01	**-0.34***	-0.21	-0.11
	Cr		**1**	0.03	0.21	0.14	**0.35***
	Co			**1**	-0.04	0.10	**0.58****
	Pb				**1**	**0.76****	**-0.38***
	Cd					**1**	**-0.41****
	Ni						**1**
Mergapan	Distance	**1**	0.19	-0.03	0.00	**-0.45****	0.16
	Cr		**1**	**0.77****	**-0.57****	0.03	**-0.30***
	Co			**1**	**-0.67****	**0.35***	**-0.49****
	Pb				**1**	-0.28	**0.70****
	Cd					**1**	**-0.53****
	Ni						**1**

** Correlation is significant at P<0.01 level (2-tailed). * Correlation is significant at P< 0.05 level (2-tailed).

Table12. Total heavy metal concentrations in soils from selected studies in Iraq.

Location	Cr	Co	Pb	Cd	Ni	References
	mg kg^{-1}					
Duhok City (roadside)	3.42	40.54	88.28	3.42	78.73	Yousif, 2016
Hilla City (roadside)	40.2	42.25	430.8	2.6	81.6	Al-Fatlawi & Al-Alwani, 2012
Baghdad City (residential area)	23.09	n/a	87.06	0.29	86.76	Al-Obaidy & Al-Mashhadi, 2013
Baghdad City (commercial area)	24.21	n/a	110.30	0.45	72.76	
Baghdad City (industrial area)	32.69	n/a	129.99	0.94	25.74	
Fallujah City (mixed)	11.59	3.43	3.82	0.64	8.96	Salah et al., 2103
Baghdad City, (agricultural field)	0.84	1.08	8.34	1.58	46.31	Fayad et al., 2013
Baghdad City (playground)	84.0	11.0	7.1	n/a	104.0	Hamad et al., 2014
Kirkuk City (city center)	n/a	n/a	21.73	4.21	n/a	Hussain, 2016
Kirkuk City (outside the city, mixed)	n/a	n/a	13.25	2.38	n/a	
Sulaimani (low traffic road)	n/a	n/a	0.33	78.9	n/a	Khorshid & Bruhn, 2016
Sulaimani (semi-heavy traffic road)	n/a	n/a	0.24	59.4	n/a	
Sulaimani (heavy traffic road)	n/a	n/a	0.54	71.1	n/a	

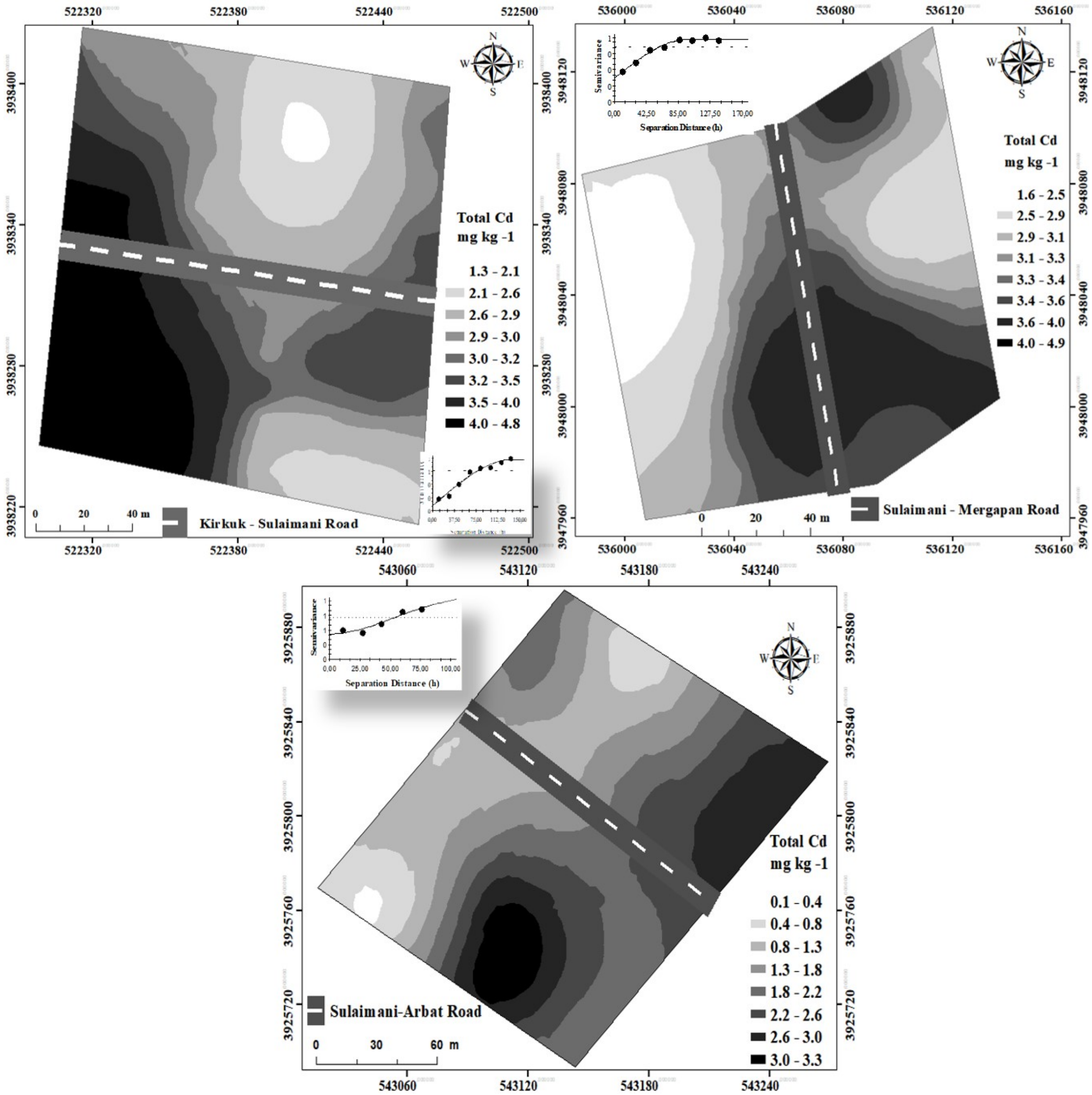

Figure 2. Spatial distribution of Cd concentration on roadside soils of three major roads.

that significant correlations of Cu or Cd contents of roadside soils with Zn and Pb contents is resulted from vehicular heavy metal emission process. High correlation between Cd and Pb contents is consistent with research reported by Sun et al., (2010) stated that high correlation between two heavy metals is an indication of similar pollution level and similar pollution sources.

3.3. Variation in Heavy Metal Concentration with Distance to Road Edges

The Cd concentration of roadside soils in Mergapan road (r= -0.45, P=0035) and Pb concentration in Kirkuk road (r= -0.34, P=0.0324) were inversely correlated with road distance (Table 11). There were no other significant correlations between road distance and heavy metal concentrations of roadside soils. However, the concentrations of Co, Pb and Cd in roadside soils at 25 m and 50 m distances were lower compared to heavy metals of roadside soils at 1m and 15 m distances. Spatial distribution maps of Cd and Pb do not show a significant decrease or increase in the concentrations as moved away from the both roadsides (Figs. 2 and 3).

Similar to the previous results on variation of heavy metal contents in roadside soils reported by (Saeedi et al., 2009; Yi et al., 2012; Hui et al., 2017), the distribution of the heavy metal concentrations was all belt-shaped as a whole and showed significant differences among sampling distances.

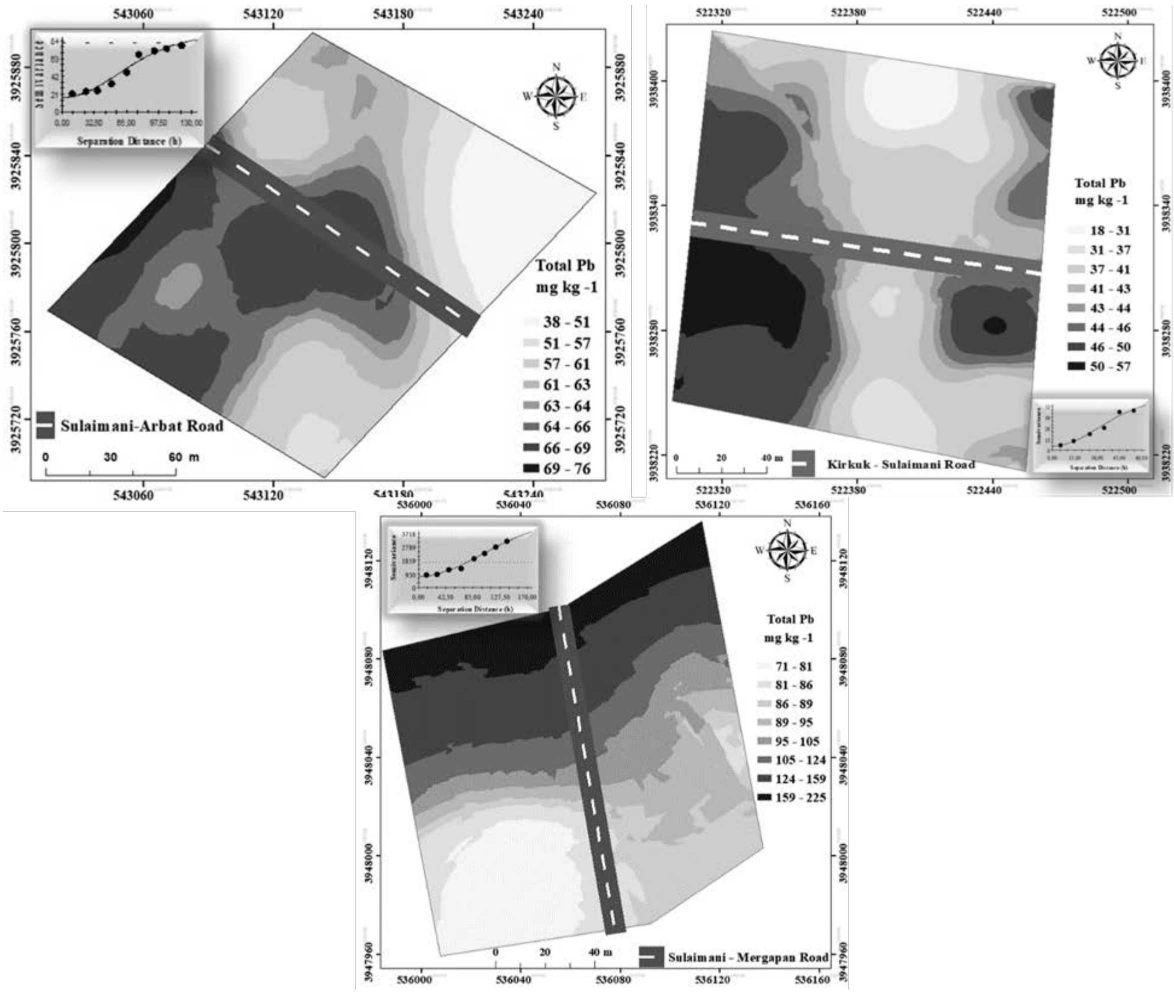

Figure 3. Spatial distribution of Pb concentration on roadside soils of three major roads.

The concentrations of all metals were the highest within 15 m distance from the both sides of road edges in Arbat road. The increased pollution level of the soils at the closest distance to the road could be attributed to the highest input rates of heavy metals with airflow, runoff- and splashing water in this area. The distribution patterns of heavy metals on Kirkuk and Mergapan roads were similar to Arbat road. Others reported higher rates of heavy metals accumulations in the closer distances from road edges compared to our findings (Kocher et al., 2005).

The difference in heavy metal accumulation distance may be related to the lack of dense vegetation on road edges in the study area that may restrain the further spread of pollutants. Sand content of soils in all three sites had high variability and sand content was as high as 79.1% in Kirkuk and 72.9% in Mergapan roads (Table 6). Due to the heavy rainfall or irrigation, heavy metals in sandy soils with low organic matter may be leached down to soil profile (Jalali & Khanboluki, 2007). Leaching of heavy metals below 20 cm soil depth may also cause to the lower heavy metal concentration of soils in 0-20 cm depth at 1 m distance compared to the heavy metal concentration at 15 m and in some cases 25 m and 50 m distances. Similar to our assumption, Kocher et al. (2005) also stated that higher infiltration rate in 1 m distance in contrast to 2.5 m led to lower Cr concentration of soils in 1 m distance.

4. CONCLUSIONS

In this study, heavy metal concentrations of roadside soils relevant to the distance from road edges in three different roads connecting Sulaimani city to the Arbat, Kirkuk and Mergapan cities were determined and evaluated for potential environmental risks. The concentrations of all heavy metals significantly differed among three roads. The investigation of 120 soil revealed a clear accumulation of Pb, Cd and Ni in roadside soils.

Strong positive correlation between Ni & Co in Arbat, Ni & Pb in Mergapan, Cd & Pb in Kirkuk roadside soils shows the common sources of these heavy metals. The results showed that mean concentrations of all heavy metals determined were significantly higher than the global background values of heavy metals. Since the routes of major roads in the region mainly fallows the valleys which are the most important sources of agricultural production of the country, the increased concentration of heavy metals should seriously be taken into account to prevent contamination of foods grown in these fields.

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