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An Assessment of Heavy Metal Soil Contamination in a Steel Factory and the Surrounding Area in Erbil City

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Abstract

The objective of the current study is to assess the soil contamination caused by a steel factory to the surrounding areas in Erbil city. The highest value of all metals (with the exception of Al) was observed in the Erbil Steel Company (E.S.C.). The mean concentration of heavy metals followed this pattern: Fe > Al > Zn > Mn > Ti > Pb > Cu > Ni > Cr > V > Co > As ≥ Mo > Cd. Only the concentration of Ni (70-181 ppm) exceeded the WHO limits in all the studied sites. Soil pollution was assessed using many indices including: index of geoaccumulation (I_{geo}), enrichment factor (EF), contamination factor (CF), degree of contamination (C_{deg}), pollution load index (PLI), element contamination index (ECI) and the overall metal contamination index (MCI) using Al as a reference element. In comparison with the local soil backgrounds from Erbil city, moderate contamination was observed generally in the Sahdawa, Shamamal and Sardasht areas with As, Co, Cr, Mn, Mo, Ni, Ti, V and Zn. However, Sahdawa was found considerably contaminated by Pb (CF = 4.79). Sites (2-8) have a considerable degree of contamination ($16 \leq C_{deg} < 32$). PLI in all the studied sites (except for Sardasht) indicated a deterioration in the site quality (PLI > 1). The R-mode factor analysis extracted three factors: first, the metals coming mainly from the E.S.C. activities accounting for 72.292 % of the total variance. Second, the lithogenic factor accounting for 14.638 % of the total variance, and finally the sampling date accounting for 6.667% of the total variance.

Keywords: Soil pollution; Heavy metals; Steel factory.

1. Introduction

Environmental pollution is the addition of substances by human activities to the environment creating health risks to humans or damaging the natural ecosystems (Radojevic and Bashkin, 2006). The soil ecosystem is considered as a complex, living, and dynamic component that may get polluted from anthropogenic activities (e.g industrial areas). When the toxic metals, trace elements and other organic substances are accumulated on the soil, the pollutants get deposited on the soil surface (Sharma and Raju, 2013). These pollutants are sometimes carried by wind and rain from a pollution source to a great distance. (Stanley et al., 2014).

One of the industrial establishments that emit pollutants in the form of dust and gases which find their way into the soil is steel factories. Iron is the second most abundant metal on earth, and is present in very insoluble compounds (oxides-hydroxides) in aerobic environments (Howard, 1999). Most of the living systems need iron, since this metal has two readily available ionization states, Fe(II) and Fe(III), and is thus often used as a cofactor for oxidation-reduction enzymes (Guerinot, 1994). High concentrations of metals including iron may inhibit and kill microorganisms, because it catalyzes the production of free radicals (Byers and Arceneaux, 1998). The production of steel is vital for the economic growth, but its production is a major source of pollution. Steel production is often associated with significant dust particle pollution which can remain airborne and can spread over large areas through wind and rain accumulating in soils and plants (Mlitan, 2013). Dust from steel and other industrial factories lead to considerable changes in the soil pH and the accumulation of emitted metals in soil which may affect both the composition and physiological processes of microorganisms (Wuana and Okieimen, 2011). Solid and liquid wastes, including fumes generated from the steel plant and the raw materials usually contain notable amounts of heavy metals such as arsenic (As), cadmium (Cd), mercury (Hg), manganese (Mn), copper (Cu), cobalt (Co), nickel (Ni), zinc (Zn), lead (Pb) and bismuth (Bi) which may be released into the environment and cause environmental health problems (Namuhani and Kimumwe, 2015). With the global changes resulting in new challenges for the environmental protection and conservation, there is a big need for baseline data to evaluate the potential risks of the released pollutants as a result of steel production to the ecosystems (Amune et al., 2012). From a public health standpoint, it is extremely important to assert that heavy metals are transported via food chains either from domestic or wild animals, or directly from crops to humans (Radojevic and Bashkin, 2006). In the Kurdistan Region and many other areas of the world, there is a fundamental conflict between the need to develop the national economy, and the potentially

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adverse environmental effects that may be associated with such economic and industrial growth.

This study is aimed at investigating the possible problems of pollution with heavy metals deposited from the Erbil Steel Factory in the surrounding environment over the last years. The analysis will be done using different contamination index methods of geoaccumulation index (I_{geo}), enrichment factor (EF), contamination factor (CF), degree of contamination (C_{deg}), pollution load index (PLI), element contamination index (ECI) and the overall metal contamination index (MCI) using Al as a reference element to differentiate the natural components from the anthropogenic ones. In addition, the soil contamination risk assessment will be investigated based on a comparison between a measured level of contamination in the soils with uncontaminated local soil values and the average soil backgrounds.

2. Materials And Methods

2.1. The Study Area

Erbil, the capital of the Iraqi Kurdistan Region is situated 414 meters above the sea level, on longitude 43º 15' E and latitude 35º 11' N to 37º 24 N' (WFP, 2002). Erbil soils are calcareous, originating from limestone and dolomite in different formations. The topsoil is calcareous with a 1-2% organic matter and exists in areas with hot-dry summers and cold rainy winters (FAO, 2001). The Erbil climate is somehow similar to the Irano-Turanian type of the semi-arid zones, characterized by cold winters, mild-growing periods in spring and hot summers (Khudhur and Khudhur, 2015).

The Erbil Steel Company (ESC) is the most prominent heavy-industry establishment in the Kurdistan Region of Iraq. It was constructed in 2006 in the Northern Iraq. Steel production started in December of 2007 with an annual production capacity of 240000 tons (ESC, 2016). The company is situated to the west of Erbil city. Originally the company started working only with the gathered iron scrap developing afterwards, into one of the biggest iron-production compounds in the region (Khudhur et al., 2016). For the sake of the present study, nine sites were selected on the basis of distance from the factory. The coordinates of the locations were taken by GPS (GARMIN) with accuracy of 5m (Table 1). The studied sites are: (1) Erbil Steel Company, (2) Khazna, (3) Tarjan, (4) Binberz, (5) Nogharan, (6) Sahdawa, (7) Qaryatagh, (8) Shamamal and (9) Sardasht and the last sample was collected from the Garden Soil in the College of Science used as control (Figure 1).

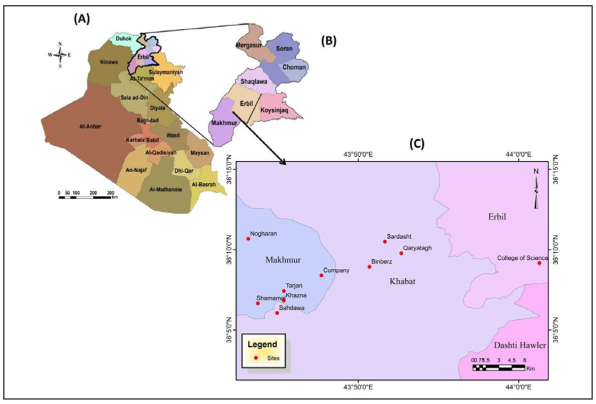

Figure 1. Map showing: (A) Iraq, (B) Erbil city and (C) the studied area.

Table 1. Detailed sampling locations around Erbil Steel Company.

Site No.	Site name	Coordination of locations	
		North	East
S1	Erbil Steel Company (E.S.C.)	36° 08' 24.00"	43° 47' 42.00"
S2	Khazna	36° 06' 50.40"	43° 45' 21.60"
S3	Tarjan	36° 07' 26.40"	43° 45' 21.60"
S4	Binberz	36° 08' 56.40"	43° 50' 42.00"
S5	Nogharan	36° 10' 40.80"	43° 43' 08.40"
S6	Sahdawa	36° 06' 03.60"	43° 44' 56.40"
S7	Qaryatagh,	36° 09' 46.80"	43° 52' 40.80"
S8	Shamamal	36° 06' 39.60"	43° 43' 44.40"
S9	Sardasht	36° 10' 30.00"	43° 51' 39.60"
S10	Science College (Control)	36° 09' 10.80"	43° 51' 39.60"

2.2. The Soil Sampling

Surface soil samples were collected from soils exposed to both waste and air effluents of the Steel Factory during the winter of 2014. In each case, the soil was scraped (5-15 cm depth) into a clean plastic bag using a stainless steel spoon. A total of three pooled samples were taken from each location collecting thirty samples from all the study areas. Soils were air-dried at room temperature (25 C°), then crushed and sieved through 2-mm stainless sieve to remove debris (Sheppard and Addison, 2008).

2.3. Analysis of some Physiochemical Characteristics of the Soil

Soil texture and particle-size distribution, moisture content, pH value, and organic matter were determined according to the methods described by (Ryan, et al. 2001). Soil texture and particle-size distribution were determined by hydrometer method; moisture content was determined by gravimetric method; soil pH was determined by using calibrated pH-meter (JENWAY 3505) and the soil organic matter was determined by Walkly-Black procedure (1934).

2.4. Determination of Heavy Metal Concentration in the Soil

The soil samples were analysed for fourteen metals including: aluminium (Al), arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), titanium (Ti), vanadium (V) and zinc (Zn). The soil samples were digested in aqua regia using 3:1 nitric to hydrochloric acids as given in (ALS, 2015). Metals in the final solutions were determined using ICP-Mass Spectroscopy (ICP-MS).

2.5. Soil Contamination Assessment Methods

The assessment of soil contamination was carried out by various methods. For the sake of this study, different indices have been applied to assess the heavy-metal distribution and contamination in the Erbil Steel Company and the related area. The indices used are: geoaccumulation index (I_{geo}), enrichment factor (EF), contamination factor (CF), degree of contamination (C_{deg}), pollution load index (PLI), element contamination index (ECI) and the overall metal contamination index (MCI). A normalized indices approach for element concentration is adopted in this study using world uncontaminated background soils, namely average soil backgrounds (Kabata-Pendias and Mukherjee, 2007), and local soil backgrounds (Alnaqshabandi, 2014) (table 2). Also

Aluminium as a metal of normalization was employed for the sake of this study.

Table 2. Background concentration of heavy metals in earth crust (Alnaqshabandi, 2014 and Kabata-Pendias and Mukherjee, 2007).

Elements \ Background		Local	Average soil
Al	%	1.85	3.995
Fe		2.43	1.749
Ti		0.04	0.7038
As	ppm	6.23	6.83
Cd		0.25	0.41
Co		14.35	11.3
Cr		70	59.5
Cu		22.75	38.9
Mn		591	488
Mo		0.59	1.1
Ni		107.5	29
Pb		8.35	27
V		52.4	129
Zn		52.75	70

2.5.1. Index of Geoaccumulation (Igeo)

The index of geoaccumulation (I_{geo}) is a quantitative measure of the extent of metal pollution in the studied soil. It is calculated using the geo-accumulation index proposed by Muller (1969) and given by (Nowrouzi and Pourkhabbaz, 2014). This index (I_{geo}) of heavy metal is calculated using the following mathematical relation:

$I_{geo} = \log_2 [C_n/1.5B_n]$ …………….. (1)

where C_n is the measured total concentration in the soil with the metal n,. B_n is the background value for the metal n,; the factor 1.5 (correction factor) is used because of possible variations of the background data due to lithological variations.

2.5.2. Enrichment Factor

The Enrichment Factor (EF) is a normalization method proposed by Simex and Helz (1981) to assess the concentration of the metals (Salah et al., 2012). For the present study, EF has been chosen to normalize metal concentrations using Al. The EF is defined as follows:

$EF = (M/Al)_{Sample} / (M/Al)_{Background}$ …………….. (2)

Where $(M/Al)_{Sample}$ is the ratio of metal and Al concentrations in the sample $(M/Al)_{Background}$ is the ratio of metal and Al concentrations of the background.

2.5.3. Contamination Factor (CF)

The contamination Factor (CF) is the concentration of each metal in the soil divided by the background concentration of the metal (concentration in unpolluted soil).

$CF = C_{Heavy\ metal} / C_{Background}$ …………….. (3)

The background concentrations were calculated from the heavy metal concentration in unaffected soils of the studied area (Bambara et al., 2015).

2.5.4. Degree of Contamination (C_{deg})

It is a modified and generalized form of the degree of contamination (C_{deg}) formula (Aikpokpodion et al., 2010); this formula was also proposed by (Hakanson, 1980). It is calculated by the following equation:

$C_{deg} = \sum(C_m / B_m)^i$ …………….. (4)

where i represents the respective metals (i.e. Al, As, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Ti, V and Zn), C_m is the measured concentration in the soil, and B_m is the background concentration value of metal (m) within the area of study. For the C_{deg}, Hakanson recognized four descriptive classes, where by $C_{deg} < 8$ implies a low degree of contamination. C_{deg} 8-16 means a moderate degree of contamination. C_{deg} 16-32 indicates a considerable degree of contamination and $C_{deg} \geq 32$ implies a very high degree of contamination.

2.5.5. Pollution Load Index (PLI)

The Pollution load index (PLI) provides an empirical index that comparatively assesses the level of heavy metal pollution. The PLI for the various sampling areas were determined as the geometric mean of all assessed CF of a sampling site (Afrifa et al., 2013).

$PLI = (CF_1 \times CF_2 \times CF_3 \times .... \times CF_n)^{1/n}$ …………….. (5)

$_n$ is the number of metal index providing a simple, comparative means for assessing the level of heavy metal pollution. A value of PLI < 1 denotes perfection. PLI = 1 indicates that only baseline levels of pollutants are present, and PLI > 1 would indicate deterioration of the site quality (Bambara et al., 2015).

2.5.6. The Element Contamination Index and the Metal Contamination Index

The Element contamination index (ECI) and the overall metal contamination index (MCI) are expressions of a single metal contamination within a sample or combined metal contamination for a sample relative to the background values of the respective metal (Singh et al., 2015) . They are expressed as:

$ECI = (C_m - B_m / B_m)$ …………….. (6)

$MCI = \sum(C_m - B_m / B_m)^i$ …………….. (7)

Where i C_m and B_m are as defined earlier. According to (Aikpokpodion et al., 2010), MCI was designed to describe general trace elements contamination. MCI of < 5 implies a very low contamination; MCI = 5-10 means low contamination; MCI = 10-25 denotes medium contamination; MCI = 25-50 means high contamination; MCI = 50-100 implies a very high contamination and MCI > 100 implies an extremely high contamination.

2.6. Statistical Analysis

Results were processed and analyzed using Microsoft Excel 2010 and SPSS Statistical Analysis Package for Windows®. Data is reported as mean ± standard error of the mean. For physicochemical properties, one-way analysis of variance (ANOVA) was performed and the multiple comparisons among the studied sites were done by using Duncan's test. A p-value of <0.05 is considered significant. Arc GIS "Geographic Information system" (version 10.2) was used for mapping the heavy metal distribution in the studied areas. The concentration of heavy metals and physicochemical properties of the studied soil samples were treated statistically by Person's correlation coefficient and R-mode factor analysis to determine the relation between these elements in the different locations of the study area.

3. Results and Discussion

3.1. Soil Physicochemical Properties

Soil water affects the moisture available to organisms, aeration status, nature and amount of soluble materials, osmotic pressure, and the pH of the soil solution (Paul, 2007). The current study has showed a moisture range of

10.26±0.040 and 21.98±0.058 % in control soil and Sardasht area respectively. Significant differences ($p<0.05$) were observed among the studied sites (table 3). This result is consistent with other finding in earlier studies conducted by Khudhur et al. (2016) on the soils of these areas. Particle-size distribution and soil texture classes were presented in table (3). Different soil texture classes were found varying from loam, sandy loam, and sandy clay loam to loamy sand.

Results show that the soil pH ranged between 7.48 and 8.83 (table 3) and this finding suggests that the studied soils are mostly in neutral to sub-alkaline condition which can be attributed to the high content of carbonate, ash and cinders of anthropogenic origin, and to the alkali components in the atmosphere which may eventually deposit on the ground and affect the soil pH (Al Obaidy and Al Mashhadi, 2013).

The soil organic matter of the Erbil Steel Company was significantly different ($p<0.05$) from the other sites, and has the highest organic matter content of 48.20±4.447 $g.Kg^{-1}$ (table 3). Zhang and Wang (2007) confirm this observation by stating that when the heavy metal pollution in the soil increases, the particulate organic matter and its proportion in the total soil organic C increase as well. Heavy metals are largely enriched with particulate organic matter, which could impact the further mineralization of soil organic matter.

Table 3. Physicochemical properties of the studied soils as (mean ± S.E.).

Site No.	Site name	Moisture %	Particle size distribution			Texture class	pH	Soil organic matter $g.Kg^{-1}$
			Clay %	Silt %	Sand %			
S1	E.S.C.	14.04±0.176^{cd}	23.39	32.17	44.44	Loam	8.83±0.176^{a}	48.20±4.447^{a}
S2	Khazna	15.76±0.069^{bc}	5.99	22.46	71.55	Sandy Loam	7.48±0.069^{e}	10.24±0.136^{def}
S3	Tarjan	20.44±0.023^{ab}	28.33	22.04	49.63	Sandy Clay Loam	7.79±0.023^{d}	20.21±0.289^{c}
S4	Binberz	20.07±0.136^{ab}	21.87	40.62	37.51	Loam	7.87±0.136^{cd}	2.77±0.000^{f}
S5	Nogharan	16.39±0.087^{bc}	6.01	27.04	66.95	Sandy Loam	8.15±0.087^{bc}	30.63±0.365^{b}
S6	Sahdawa	21.89±0.075^{a}	19.42	38.85	41.73	Loam	8.13±0.075^{bc}	32.79±0.454^{b}
S7	Qaryatagh	13.96±0.058^{cd}	17.63	35.26	47.11	Loam	8.10±0.058^{bc}	7.30±0.056^{ef}
S8	Shamamal	14.26±0.072^{cd}	14.62	35.10	50.28	Loam	8.13±0.072^{bc}	14.75±0.200^{cde}
S9	Sardasht	21.98±0.058^{a}	3.25	22.72	74.04	Loamy Sand	8.10±0.058^{bc}	35.83±0.477^{b}
S10	Control	10.26±0.040^{d}	17.87	33.19	48.93	Loam	8.38±0.040^{b}	16.63±0.000^{cd}
Maximum		21.98	28.33	40.62	74.04		8.83	48.20
Minimum		10.26	3.25	22.04	37.51		7.48	2.77

**Different letters means significant differences between the studied sites $p<0.05$.*

3.2. Soil Metal Contents

Heavy metals are especially dangerous because of their persistence and toxicity. Soil acts as a sink for heavy metals through sorption, complexation, and precipitation reactions. Due to proximity to humans, accumulation of harmful substances in urban soils is of great concern. Heavy metals may be transferred to human bodies by way of ingestion, inhalation and dermal contact, or through the food chain (Salah et al., 2013). According to the United Nation Environmental Program (UNEP), Percy et al. (1997) sited in (Elgawad et al., 2007) reported that out of the forty heavy metals in the earth, arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg) and nickel (Ni) are the most common heavy metals that are considered pollutants. In particular the metals arsenic, antimony, lead, mercury, copper, chromium and chromium VI, as the soluble compound of chromium, can have adverse harmful effects on human health and the environment and should thus be tested (PUMA safe, 2009). As shown in table (table 4), the concentrations of detected metals showed variable values depending on the sampling sites. It is worth mentioning that in comparison to the other sites, the soil samples collected in the factory exhibited higher concentration of metals (except for aluminum). Those results are consistent with the findings of Khudhur et al. (2016) in the Steel Company. The increment of soil metals in the same area may be a result of precipitation of iron and steel factory dusts over the years (Mlitan, 2013). Moreover, the highest Al content was detected in the Binberz soil. This difference could be relevant to the climate, soil origin, composition or human activities (Mlitan, 2013).

The highest value of all the studied metals (except for Al) was observed in Erbil Steel Company. The results showed variations in the concentrations of the elements, which possibly indicate the effects of the soil type, type of the parent rocks and anthropogenesis and industrial activities The release of industrial wastes directly into the environment without any treatment or fuel incinerator products can also be regarded as other sources of the soil pollution (Mohammed and Abdullah, 2016). The lowest values of most of the studied metals are as follows: Al (1.13 %), Fe (1.87 %), As (4 ppm), Co (11 ppm), Cr (52 ppm), Mn (395 ppm), Ni (70 ppm), Pb (9 ppm) and V (39 ppm). They were observed in the Sardasht soil. The results regarding As, Cr and Mn contents are in agreement with those of Rahman et al. (2012); the results of Cd and Cu agree with those of (Asaah et al., 2006) and the lowest Cd and Co and the highest Cr values are in consistence with those of Odat (2015). The world median content of Cr in soils has been established as 54 ppm due to its abundance in the parent material. The Cr content of surface soils is known to have increased due to pollution by various sources. Moreover, the ranges of As (4-13 ppm), Cr (52-134 ppm) and Ni (70-181 ppm) agree with the ranges obtained by Mohammed and Abdullah (2016) in Baghdad. The lowest values of Ti (0.03 %), Cu (25 ppm) and Zn (61 ppm) were observed in Nogharan, Qaryatagh and Binberz respectively. The values of 0.5 and 1 ppm as lowest values for both Cd and Mo were observed in all of the studied sites with the exception of the Erbil Steel Company.

The results of the occurrence of the metals in all the studied sites indicated that Fe has emerged as the dominant metal, while Cd has the lowest concentration. The studied metals have shown the following sequence: Fe > Al > Zn > Mn > Ti > Pb > Cu > Ni > Cr > V > Co > As ≥ Mo > Cd.

The WHO concentration limits in the soil are 100 ppm for Pb, 3 ppm for Cd, 50 ppm for Ni, 150 ppm for Cr, 40 ppm for As and 300 ppm for Zn (Bambara et al., 2015). The concentration of Pb, Cd, Cr and Zn obtained in the studied sites (with the exception of Erbil Steel Company) are less than the WHO concentration limits. The concentration of Ni in all of the studied sites has exceeded the WHO limits, whereas the concentration of As has not reached the WHO limits in all the studied sites.

Table 4. Mean contents of heavy metals in the studied soils.

Metals \ Site No.		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Maximum	Minimum
Al	%	1.32	1.93	1.8	2.17	1.68	1.89	2.13	1.81	1.13	1.65	2.17	1.13
Fe	%	8.76	2.47	2.38	2.48	2.13	2.51	2.46	2.63	1.87	2.06	8.76	1.87
Ti	%	0.1	0.04	0.04	0.05	0.03	0.04	0.04	0.07	0.06	0.04	0.1	0.03
As	ppm	13	5	5	6	5	5	7	11	4	5.5	13	4
Cd	ppm	8.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	8.4	0.5
Co	ppm	20	15	15	15	13	15	14	17	11	12	20	11
Cr	ppm	134	68	68	68	62	70	67	91	52	52	134	52
Cu	ppm	258	28	30	27	31	36	25	45	26	27	258	25
Mn	ppm	1420	531	556	510	500	633	528	630	395	518	1420	395
Mo	ppm	13	1	1	1	1	1	1	1	1	1	13	1
Ni	ppm	181	109	104	102	88	105	101	142	70	88	181	70
Pb	ppm	294	13	15	9.5	15	40	12	14	9	12	294	9
V	ppm	59	49	47	53	43	45	52	53	39	40.5	59	39
Zn	ppm	7485	71	73	61	92	93	66	67	70	81.5	7485	61

3.3. Results of the Soil Contamination Assessment

3.3.1. Index of Geoaccumulation (Igeo)

The calculated I_{geo} values are shown in table (5a). Compared to the local soil background, the I_{geo} values indicated uncontaminated/moderately contaminated soils for: As in both E.S.C. and Shamamal (I_{geo} = 0.48 and 0.24); Cr, Mn and Ni in E.S.C. (I_{geo} = 0.35, 0.68 and 0.17); Cu in Sahdawa and Shamamal (I_{geo} = 0.08 and 0.40); Pb in Khazna, Tarjan, Nogharan and Shamamal (I_{geo} = 0.05, 0.26, 0.26 and 0.16); and Zn in Nogharan, Sahdawa and control soils (I_{geo} = 0.22, 0.23 and 0.04); Ti in both E.S.C. and Shamamal (I_{geo} = 0.74 and 0.22) as well as Cd and Mo in all sites (except for The Erbil Steel Company) and this result is consistent with Odat (2015). The non-contamination to moderate contamination in Khazna, Tarjan, Nogharan and Shamamal with Pb could be attributed to the road network on the west side of the Factory that supplies raw materials to the factory; the high heavy metal load on this side is attributed to anthropogenic effects such as the burning of fossil fuel, wear and tear of tires, and dust generation during transportation of raw materials (Namuhani and Kimumwe, 2015).Moderate contamination was proven in both E.S.C. with Fe (I_{geo} = 1.27) and Sahdawa with Pb (I_{geo} = 1.68). The Erbil Steel Company was found moderately/strongly contaminated with Cu (I_{geo} = 2.93), strongly contaminated with Mo (I_{geo} = 3.89) and strongly/extremely contaminated with Cd (I_{geo} = 4.51) and Pb (I_{geo} = 4.57).

Based on the average soil background, the I_{geo} values indicated uncontaminated/moderately contaminated soils for: As in E.S.C. and Shamamal (I_{geo} = 0.35 and 0.10); Co and Mn in E.S.C. (I_{geo} = 0.24 and 0.96) respectively; Cr in E.S.C. and Shamamal (I_{geo} = 0.59 and 0.03) and Ni in Sardasht soil. It is evident that the I_{geo} values for Fe (in E.S.C.) and Ni (except for E.S.C. and Sardasht) are ($1 < I_{geo} < 2$) (table 5b) and can be classified as moderately contaminated. The Erbil Steel Company was found moderately/strongly contaminated by Cu, Mo, Ni and Pb (I_{geo} = 2.15, 2.99, 2.07 and 2.87) respectively. It was found strongly contaminated by Cd (I_{geo} = 3.79) and extremely contaminated with Zn (I_{geo} = 6.18).

Table 5 a. Geoaccumulation Index (I_{geo}) of trace elements based on local and average soil backgrounds in the study area.

	Elements / Site No.	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Ti	V	Zn
Local background	S1	-1.08	0.48	4.51	-0.11	0.35	2.93	1.27	0.68	3.89	0.17	4.57	0.74	-0.42	6.59
	S2	-0.53	-0.91	0.42	-0.52	-0.63	-0.29	-0.56	-0.74	0.18	-0.57	0.05	-0.59	-0.68	-0.16
	S3	-0.63	-0.91	0.42	-0.52	-0.63	-0.19	-0.62	-0.68	0.18	-0.64	0.26	-0.59	-0.75	-0.12
	S4	-0.36	-0.64	0.42	-0.52	-0.63	-0.34	-0.56	-0.80	0.18	-0.66	-0.40	-0.26	-0.57	-0.38
	S5	-0.73	-0.91	0.42	-0.73	-0.76	-0.14	-0.78	-0.83	0.18	-0.88	0.26	-1.00	-0.87	0.22
	S6	-0.56	-0.91	0.42	-0.52	-0.59	0.08	-0.54	-0.49	0.18	-0.62	1.68	-0.59	-0.81	0.23
	S7	-0.38	-0.42	0.42	-0.62	-0.65	-0.45	-0.57	-0.75	0.18	-0.68	-0.06	-0.59	-0.60	-0.26
	S8	-0.62	0.24	0.42	-0.34	-0.21	0.40	-0.47	-0.50	0.18	-0.18	0.16	0.22	-0.57	-0.24
	S9	-1.30	-1.23	0.42	-0.97	-1.02	-0.39	-0.97	-1.17	0.18	-1.21	-0.48	0.00	-1.02	-0.18
	S10	-0.75	-0.77	0.42	-0.85	-1.02	-0.34	-0.83	-0.78	0.18	-0.88	-0.06	-0.78	-0.96	0.04
Average soil	S1	-2.19	0.35	3.79	0.24	0.59	2.15	1.75	0.96	2.99	2.07	2.87	-3.42	-1.72	6.18
	S2	-1.64	-1.04	-0.30	-0.18	-0.39	-1.06	-0.09	-0.47	-0.73	1.33	-1.65	-4.74	-1.99	-0.57
	S3	-1.74	-1.04	-0.30	-0.18	-0.39	-0.96	-0.14	-0.40	-0.73	1.26	-1.44	-4.74	-2.05	-0.53
	S4	-1.47	-0.78	-0.30	-0.18	-0.39	-1.12	-0.08	-0.52	-0.73	1.24	-2.10	-4.42	-1.88	-0.79
	S5	-1.84	-1.04	-0.30	-0.38	-0.53	-0.92	-0.30	-0.55	-0.73	1.02	-1.44	-5.16	-2.18	-0.19
	S6	-1.67	-1.04	-0.30	-0.18	-0.35	-0.70	-0.06	-0.21	-0.73	1.28	-0.02	-4.74	-2.11	-0.18
	S7	-1.50	-0.55	-0.30	-0.28	-0.42	-1.23	-0.09	-0.47	-0.73	1.22	-1.76	-4.74	-1.90	-0.67
	S8	-1.74	0.10	-0.30	0.00	0.03	-0.38	0.00	-0.22	-0.73	1.71	-1.54	-3.93	-1.88	-0.65
	S9	-2.42	-1.36	-0.30	-0.63	-0.78	-1.17	-0.49	-0.89	-0.73	0.69	-2.18	-4.16	-2.32	-0.59
	S10	-1.87	-0.90	-0.30	-0.50	-0.78	-1.12	-0.35	-0.50	-0.73	1.02	-1.76	-4.94	-2.27	-0.37

Table 5 b. Index of geoaccumulation (I_{geo}) for contamination levels in the soils.

I_{geo} Class	I_{geo} Value	Contamination Level
0	$I_{geo} \leq 0$	Uncontaminated
1	$0 < I_{geo} < 1$	Uncontaminated/moderately contaminated
2	$1 < I_{geo} < 2$	Moderately contaminated
3	$2 < I_{geo} < 3$	Moderately/strongly contaminated
4	$3 < I_{geo} < 4$	Strongly contaminated
5	$4 < I_{geo} < 5$	Strongly/extremely contaminated
6	$5 < I_{geo}$	Extremely contaminated

* *Taken from (Rahman et al., 2012).*

3.3.2. Enrichment factor

The Enrichment Factor (EF) is the relative abundance of an element in a soil compared to the bedrock. The EF was calculated by a comparison of each tested metal concentration with that of a reference metal. The normally used reference metals are Mn, Al, and Fe. In this study Al was used to keep differences between natural from anthropogenic components. according to the hypothesis that the content components in the earth crust have not been troubled or disturbed by anthropogenic activity effects. Al is chosen as the element of normalization because natural sources and natural processes are approximated equal to (98%) of the all processes that the earth evolved; i.e. the natural sources greatly dominate its contribution (Shukur and Al-Tamimi, 2016).

The results of the Enrichment Factor of the studied metals are presented in table (6a). On the basis of the local soil backgrounds while taking Al as a reference element, and according to the contamination categories established by (Loska et al., 2003) given in table (6b), most of the studied areas (except for E.S.C.) have minimal enrichment. The contamination categories of EF showed that the Erbil Steel Company has moderate enrichment for As, Cr, Mn, Ni and Ti (EF = 2.92, 2.68, 3.37, 2.36 and 3.50) respectively; significant enrichment for Cu and Fe (EF = 15.89 and 5.05) respectively; very high enrichment for Mo (EF = 30.88), and extremely high enrichment for Cd, Pb and Zn (EF = 47.09, 49.35 and 198.9) respectively. Sardasht area showed moderate enrichment with Mo (EF = 2.77), Ti (EF = 2.46) and Zn (EF = 2.17). Shamamal and Sahdawa revealed moderate enrichment with Cu and Pb (EF = 2.02 and 4.69) respectively. Cadmium caused moderate enrichment in different sites including Tarjan (EF = 2.06), Nogharan (EF = 2.20), Shamamal (EF = 2.04), Sardasht (EF = 3.27) and garden soil (EF = 2.24). Generally speaking, the soils of the study area are mainly derived from the upper cretaceous carbonate rocks. However, carbonates in general have low concentrations of Pb and Cd, so the possible source of these metals may be anthropogenic. Since the soil samples have been taken along different distances from the Erbil Steel Company, it can be considered as the main source of the metals in the soils of the study area.

Based on the average soil background, all the studied areas (except for E.S.C.) are moderately enriched by the elements Cd, Co, Cr and Fe. Moderate enrichment by Mn in all the studied areas (except for E.S.C. and Binberz). Moderate enrichment of As, Cu, Mo, Pb and Zn was found in different areas (table 6a). The elements As, Co, Cr, Fe, and Mn are significantly enriched in the Erbil Steel Company.

All the studied areas showed significant enrichment of Ni. Mohammed and Abdullah (2016) stated that Ni in soil is strongly associated with Fe and Mn oxides. Also clay minerals, in particular montmorillonite, exhibit great capability to bind this metal. The elevated Ni concentrations may be related to oil combustion and agricultural activities (phosphate fertilizers) in these areas. The Erbil Steel Company showed very high enrichment due to the elements Cu (EF = 20.07), Mo (EF = 35.77) and Pb (EF = 32.96), and showed extremely high enrichment of both Cd and Zn, with EF > 40.

Table 6 a. Enrichment factor (EF) of trace elements based on local and average soil backgrounds in the study area using Al as a reference element.

	Elements / Site No.	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Ti	V	Zn
Local background	S1	1.00	2.92	47.09	1.95	2.68	15.89	5.05	3.37	30.88	2.36	49.35	3.50	1.58	198.9
	S2	1.00	0.77	1.92	1.00	0.93	1.18	0.97	0.86	1.62	0.97	1.49	0.96	0.90	1.29
	S3	1.00	0.82	2.06	1.07	1.00	1.36	1.01	0.97	1.74	0.99	1.85	1.03	0.92	1.42
	S4	1.00	0.82	1.71	0.89	0.83	1.01	0.87	0.74	1.44	0.81	0.97	1.07	0.86	0.99
	S5	1.00	0.88	2.20	1.00	0.98	1.50	0.97	0.93	1.87	0.90	1.98	0.83	0.90	1.92
	S6	1.00	0.79	1.96	1.02	0.98	1.55	1.01	1.05	1.66	0.96	4.69	0.98	0.84	1.73
	S7	1.00	0.98	1.74	0.85	0.83	0.95	0.88	0.78	1.47	0.82	1.25	0.87	0.86	1.09
	S8	1.00	1.80	2.04	1.21	1.33	2.02	1.11	1.09	1.73	1.35	1.71	1.79	1.03	1.30
	S9	1.00	1.05	3.27	1.25	1.22	1.87	1.26	1.09	2.77	1.07	1.76	2.46	1.22	2.17
	S10	1.00	0.99	2.24	0.94	0.83	1.33	0.95	0.98	1.90	0.92	1.61	0.98	0.87	1.73
Average soil	S1	1.00	5.76	62.01	5.36	6.82	20.07	15.16	8.81	35.77	18.89	32.96	0.43	1.38	323.6
	S2	1.00	1.52	2.52	2.75	2.37	1.49	2.92	2.25	1.88	7.78	1.00	0.12	0.79	2.10
	S3	1.00	1.62	2.71	2.95	2.54	1.71	3.02	2.53	2.02	7.96	1.23	0.13	0.81	2.31
	S4	1.00	1.62	2.25	2.44	2.10	1.28	2.61	1.92	1.67	6.48	0.65	0.13	0.76	1.60
	S5	1.00	1.74	2.90	2.74	2.48	1.90	2.90	2.44	2.16	7.22	1.32	0.10	0.79	3.13
	S6	1.00	1.55	2.58	2.81	2.49	1.96	3.03	2.74	1.92	7.65	3.13	0.12	0.74	2.81
	S7	1.00	1.92	2.29	2.32	2.11	1.21	2.64	2.03	1.71	6.53	0.83	0.11	0.76	1.77
	S8	1.00	3.55	2.69	3.32	3.38	2.55	3.32	2.85	2.01	10.81	1.14	0.22	0.91	2.11
	S9	1.00	2.07	4.31	3.44	3.09	2.36	3.78	2.86	3.21	8.53	1.18	0.30	1.07	3.54
	S10	1.00	1.95	2.95	2.57	2.12	1.68	2.84	2.57	2.20	7.35	1.08	0.12	0.76	2.82

Table 6 b. Soil contamination categories based on enrichment factor (EF).

EF Value	Contamination Level
EF < 2	Minimal enrichment
EF = 2-5	Moderate enrichment
EF = 5-20	Significant enrichment
EF = 20-40	Very high enrichment
EF > 40	Extremely high enrichment

** Taken from (Loska et al., 2003).*

3.3.3. Contamination factor (CF)

The contamination factor was used to determine the contamination status of the soils. Generally the CF of the trace elements (Al, As, Co, Cr, Mn, Ni, Ti and V) of soil samples in the studied areas based on the local soil background was indicating low to moderate contamination except for Erbil Steel Company which showed considerable to very high contamination by Fe (CF = 3.60), Cd (CF = 33.60), Cu (CF = 11.34), Mo (CF = 22.03), Pb (CF = 35.21) and Zn (CF = 141.9) (table 7a). The accumulation of metals in these areas are strongly controlled by the nature of the substrate as well as the physicochemical conditions controlling dissolution and precipitation (Shukur and Al-Tamimi, 2016). The Soil of Sahdawa area revealed considerable contamination by Pb (CF<6) as given in table (7b).

Compared to the average soil backgrounds, the studied areas revealed low to moderate contamination by As and Cr. With the exception of Sardasht which revealed low contamination, the remaining areas are moderately contaminated by Co and Mn. All the studied sites (except for E.S.C.) have moderate contamination regarding the CF values for Cd and Fe. In Shamamal, moderate contamination by Cu (CF = 1.16) was found; in Sardasht by Ni (CF = 2.41) and in Sahdawa by Pb (CF = 1.48). Moderate contamination by Zn was revealed in the sites S2, S3, S5, S6, S9 and S10. Ni caused considerable contamination in all the studied sites except for E.S.C. and Sardasht where there is very high contamination with (CF = 6.24), and moderate contamination with (CF = 2.41) respectively. This can be attributed to the influence of industrial activities, agricultural runoff, and other anthropogenic inputs. The Erbil Steel Company was considerably contaminated by Fe (CF<6), and was very highly contaminated by Cd, Cu, Mo, Pb and Zn (CF > 6).

Table 7 a. Contamination factor (CF) of trace elements based on local and average soil backgrounds in the study area.

	Elements / Site No.	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Ti	V	Zn
Local background	S1	0.71	2.09	33.60	1.39	1.91	11.34	3.60	2.40	22.03	1.68	35.21	2.50	1.13	141.9
	S2	1.04	0.80	2.00	1.05	0.97	1.23	1.02	0.90	1.69	1.01	1.56	1.00	0.94	1.35
	S3	0.97	0.80	2.00	1.05	0.97	1.32	0.98	0.94	1.69	0.97	1.80	1.00	0.90	1.38
	S4	1.17	0.96	2.00	1.05	0.97	1.19	1.02	0.86	1.69	0.95	1.14	1.25	1.01	1.16
	S5	0.91	0.80	2.00	0.91	0.89	1.36	0.88	0.85	1.69	0.82	1.80	0.75	0.82	1.74
	S6	1.0 2	0.80	2.00	1.05	1.00	1.58	1.03	1.07	1.69	0.98	4.79	1.00	0.86	1.76
	S7	1.15	1.12	2.00	0.98	0.96	1.10	1.01	0.89	1.69	0.94	1.44	1.00	0.99	1.25
	S8	0.98	1.77	2.00	1.18	1.30	1.98	1.08	1.07	1.69	1.32	1.68	1.75	1.01	1.27
	S9	0.61	0.64	2.00	0.77	0.74	1.14	0.77	0.67	1.69	0.65	1.08	1.50	0.74	1.33
	S10	0.89	0.88	2.00	0.84	0.74	1.19	0.85	0.88	1.69	0.82	1.44	0.88	0.77	1.55
Average soil	S1	0.33	1.90	20.49	1.77	2.25	6.63	5.01	2.91	11.82	6.24	10.89	0.14	0.46	106.9
	S2	0.48	0.73	1.22	1.33	1.14	0.72	1.41	1.09	0.91	3.76	0.48	0.06	0.38	1.01
	S3	0.45	0.73	1.22	1.33	1.14	0.77	1.36	1.14	0.91	3.59	0.56	0.06	0.36	1.04
	S4	0.54	0.88	1.22	1.33	1.14	0.69	1.42	1.05	0.91	3.52	0.35	0.07	0.41	0.87
	S5	0.42	0.73	1.22	1.15	1.04	0.80	1.22	1.02	0.91	3.03	0.56	0.04	0.33	1.31
	S6	0.47	0.73	1.22	1.33	1.18	0.93	1.44	1.30	0.91	3.62	1.48	0.06	0.35	1.33
	S7	0.53	1.02	1.22	1.24	1.13	0.64	1.41	1.08	0.91	3.48	0.44	0.06	0.40	0.94
	S8	0.45	1.61	1.22	1.50	1.53	1.16	1.50	1.29	0.91	4.90	0.52	0.10	0.41	0.96
	S9	0.28	0.59	1.22	0.97	0.87	0.67	1.07	0.81	0.91	2.41	0.33	0.09	0.30	1.00
	S10	0.41	0.81	1.22	1.06	0.87	0.69	1.17	1.06	0.91	3.03	0.44	0.05	0.31	1.16

Table 7 b. Soil contamination categories based on contamination factor (CF).

CF Value	Contamination Level
CF<1	Low contamination
1<CF<3	Moderate contamination
3<CF<6	Considerable contamination
CF>6	Very high contamination

* *Taken from (Afrifa et al., 2013).*

3.3.4. Degree of Contamination (Cdeg)

The degree of contamination (C_{deg}) results of the soil samples in the studied area are presented in (Figure 2). Compared to the local soil backgrounds, the sites (2-8) have a considerable degree of contamination represented by (Aikpokpodion et al., 2010). Compared to the average soil backgrounds, the sites (2, 3, 4, 5 and 7) have a moderate degree of contamination ($8 \leq C_{deg} < 16$), while the sites 6 and 8 have a considerable degree of contamination ($16 \leq C_{deg} < 32$). On the basis of both local and average soil backgrounds, Sardasht and garden soil (control) have a moderate degree of contamination, while the Erbil Steel Company has a very high degree of contamination ($C_{deg} \geq 32$).

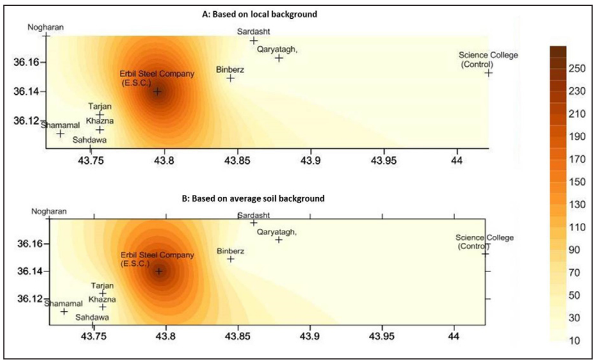

Figure 2. Degree of Contamination (C_{deg}) in the studied soils based on A: local soil backgrounds, and B: average soil backgrounds.

3.3.5. Pollution Load Index (PLI)

Pollution Load Index (PLI) was used to evaluate the extent of pollution by heavy metals in the environment. If PLI < 1, there is no heavy metal pollution (Tomlinson et al., 1980). The values of PLI > 1 imply that heavy metal pollution exists in the study areas. During this study the PLI values were > 1 on the basis of the local soil backgrounds in all the studied sites (except for Sardasht). The results indicated deterioration in the site quality (Figure 3) which can be attributed to the absence of dust collectors and a perimeter wall around the factory. Also all the fumes and gases from the factory are released into the environment. On the basis of soil average backgroundS, all the studied areas (except for E.S.C.) have denoted perfection (PLI < 1) and the Erbil steel company showed deterioration in the site quality (PLI = 3.40). These study findings are in consistent with the findings in studies conducted by Namuhani and Kimumwe (2015) around a steel-processing factory in Uganda.

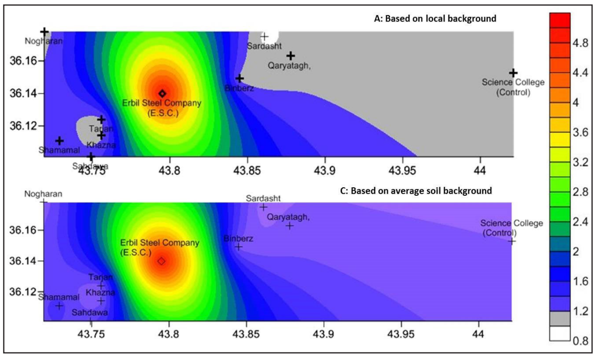

Figure 3. Pollution load index (PLI) in the studied area based on A: local soil backgrounds, and B: average soil backgrounds.

3.3.6. Element Contamination Index and Metal Contamination Index

According to the classification of MCI given by (Aikpokpodion et al., 2010), Sahdawa (MCI = 6.6) and Shamamal (MCI = 6.1), the soils revealed low contamination based on local soil backgrounds. The Erbil Steel Company showed extremely high contamination (MCI = 247.5 and 163.8) based on comparisons with local and average soil backgrounds respectively (Figure 4).

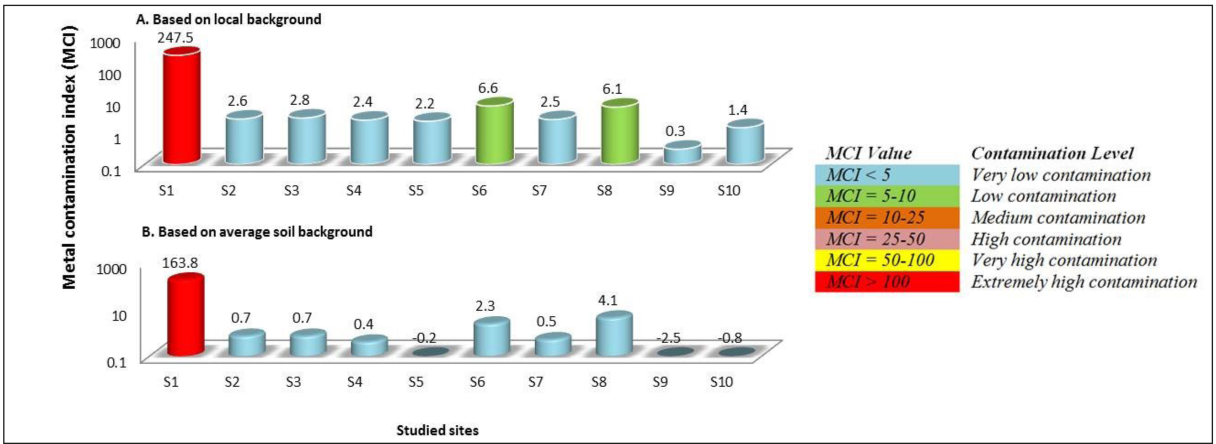

Figure 4. Metal contamination index (MCI) in the studied soils based on A: local soil backgrounds, and B: average soil backgrounds.

3.4. Results of the Statistical Correlation

Person's correlation analysis (table 8) showed high significant positive correlations ($p<0.01$) between soil organic matter and Al ($r = 0.82$). Generally there were strong positive correlations among the studied metals which may indicate that these metals are from the same source as stated by (Stanley et al., 2014). These results are also observed earlier by Khudhur et al. (2016). The strong association of Cd, Zn, and Cu indicates common sources, and that these metals may have been derived from anthropogenic sources, especially the industries (Rahman et al., 2012).

Table 8. Person's correlation among soil physicochemical properties and heavy metals in the studied areas.

	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Ti	V	Zn
pH	-0.54	0.63	0.72	0.33	0.57	0.73	0.68	0.70	0.72	0.49	0.73	0.60	0.21	0.72
S.O.M.	-0.82**	0.26	0.64	0.23	0.45	0.65	0.58	0.59	0.64	0.31	0.67	0.50	-0.09	0.64
Moisture	-0.04	-0.47	-0.25	-0.18	-0.24	-0.25	-0.25	-0.28	-0.25	-0.34	-0.22	-0.11	-0.24	-0.25
Al	1	-0.15	-0.46	0.07	-0.22	-0.46	-0.38	-0.33	-0.46	-0.09	-0.45	-0.50	0.30	-0.46
As		1	0.75	0.85**	0.92**	0.79**	0.79**	0.82**	0.75	0.93**	0.74	0.84**	0.80**	0.75
Cd			1	0.73	0.89**	1.00**	0.99**	0.97**	1.00**	0.81**	0.99**	0.82**	0.61	1.00**
Co				1	0.94**	0.77**	0.80**	0.84**	0.73	0.97**	0.75	0.72	0.90**	0.73
Cr					1	0.92**	0.93**	0.95**	0.89**	0.98**	0.90**	0.86**	0.82**	0.89**
Cu						1	0.99**	0.98**	1.00**	0.84**	0.99**	0.84**	0.63	1.00**
Fe							1	0.99**	0.99**	0.86**	0.99**	0.83**	0.69	0.99**
Mn								1	0.97**	0.90**	0.98**	0.81**	0.69	0.97**
Mo									1	0.81**	0.99**	0.82**	0.61	1.00**
Ni										1	0.81**	0.80**	0.85**	0.81**
Pb											1	0.81**	0.60	1.00**
Ti												1	0.63	0.82**
V													1	0.61
Zn														1

*** Correlation is significant at the 0.01 level (2-tailed).*

The R-mode factor analysis enhances significant single-factor anomalies and helps to discriminate between element associations that have different underlying influences controlling their concentration. The analysis groups related variables into principal associations known as factors on the basis of their mutual correlation coefficients (Asaah et al., 2006). The data of seventeen studied variables in this study were subjected to R-mode analysis which accounted for 94% of the total data variance. Only variables with loadings > 0.5 were considered significant according to Likuku et al. (2013). The resulting varimax is summarized in Table 9. The extracted factors were as follows:

Factor 1: As, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Ti, V and Zn. This factor accounts for 72.292 % of the total data variance. These metals resulted mainly from the industrial activities of the Erbil Steel Company.

Factor 2: pH, soil organic matter, Al, Cd, Cu, Mo, Pb and Zn. This factor accounts for 14.638 % of the total data variance. This variance may indicate a lithogenic origin. The metals may have come mainly from either the domestic and municipal wastes discharged into the environment, or from the metallurgical and chemical industries in addition to the dumpsites, automobiles and fuel combustion in the study area.

Factor 3: pH and soil moisture. This factor accounts for 6.667% of the total data variance, which reflects the date of the study during the winter season.

Table 9. Varimax rotated component matrix of the studied metals in the soils around the Erbil Steel Company.

No.	Studied variables	Components			Communality
		1	2	3	
1	Ph	0.352	0.695	0.466	0.825
2	OM	0.201	0.921	-0.168	0.917
3	Moisture	-0.159	0.051	-0.966	0.961
4	Al	0.061	-0.928	0.015	0.865
5	As	0.849	0.153	0.379	0.888
6	Cd	0.778	0.580	0.154	0.966
7	Co	0.979	-0.015	0.010	0.958
8	Cr	0.946	0.275	0.107	0.982
9	Cu	0.801	0.567	0.152	0.987
10	Fe	0.843	0.494	0.141	0.975
11	Mn	0.855	0.465	0.165	0.975
12	Mo	0.778	0.580	0.154	0.966
13	Ni	0.951	0.121	0.185	0.953
14	Pb	0.782	0.585	0.120	0.969
15	Ti	0.765	0.453	0.026	0.791
16	V	0.944	-0.259	0.090	0.967
17	Zn	0.777	0.582	0.154	0.966
Eigenvalues		12.290	2.488	1.133	
Percentage of Variance %		72.292	14.638	6.667	
Cumulative Percent %		72.292	86.930	93.598	

Conclusion

The findings of the current study suggest that the soil samples from the Steel Factory exhibited higher concentration of metals (except for Al). The results of metal occurrence indicated that while Fe was the most dominant metal, Cd was the least dominant. The concentration of heavy metals (except in the Erbil Steel Company) did not appear to be of serious concern, with the exception of nickel which exceeded the permissible limits set by the WHO for all studied soils. Most of the studied sites have minimal enrichment, with the exception of Erbil Steel Company which showed moderate to extremely high enrichment by the studied metals which can be considered as the main source of the metals in the soils of the surrounding studied areas of Sardasht, Shamamal, Sahdawa, Tarjan and Nogharan. It is noticeable that the pH, soil organic matter and the metal contents are in parallel increasing together. On the whole, there were strong positive correlations among the studied metals which may indicate that the metals are from the same source, and may have been derived from anthropogenic sources. According to the R-mode factor analysis, three factors were extracted. The first one refers to the industrial activities of the Erbil Steel Company; the second factor indicates lithogenic factors, and the third factor reflects the date of the study during winter season. On the whole, the soils around the Erbil Steel Company were slightly polluted with heavy metals as a result of anthropogenic influences, in particular vehicular emissions. Accordingly, immediate measures need to be taken to prevent further soil pollution by the heavy metals coming from the Erbil Steel Company.

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