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Assessment of heavy metals contamination levels in surfaces soil in Baqa'a area, Jordan

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Abstract

This study is focused to assest the heavy metals contamination levels in surface soil of Baqa'a area. Physicochemical tests have been carried out on thirteen samples from different localeties based on granulometric analysis (particle-size distribution), moisture content, pH, electrical conductivity (EC), total dissolved solids (TDS), Inductively coupled plasma (ICP) and X-Ray diffraction (XRD). Soil contamination was assessed using three indices including an index of geoaccumulation (I_{geo}), contamination factor (CF) and degree of contamination (C_{deg}). Regarding the granulometric analysis result, it can be noticed that most of the soil can be considered as sandy loam. The current study showed a moisture content of the study soil ranges from 16.2 to 18.3%, whereas the pH varies from 7.40 to 8.90. XRD results indicated that the major existing mineral is quartz, while calcite, dolomite and kaolin are minor minerals.The results of ICP showed that the soil contamination assessment allows for the arrangement of the metals from the higher to lower mean content as follows: Mn > Cr > V >Ni > Zn > Cu > Co > Pb > Cd, compared to the average soil. The I_{geo} values indicated that the results reported uncontaminated soil ($I_{geo} \leq 0$) for Cu, Pb, V and Cd, uncontaminated to moderately contaminated soil (0<Igeo<1) for Co and Mn, Zn, Ni. The results of the CF index of heavy metals of the studied samples indicated low contamination to considerable contamination, whereas the value of C_{deg} for most of the heavy metals in the studied samples indicated a moderate to a considerable degree of contamination. Exception of this conclusion can be noticed for some sites as indicated in site BR9, which shows a high degree of contamination (C_{deg}= 29.18). This site indicated also highly contaminated as approved by CF value. It can be concluded that most of reasons for high contamination in the study area are due to agricultural, industrial and dumping of waste materials that were observed in many localeties in Baqa'a area.

Keywords: Jordan, Baqa'a, soil, heavy metals, geoaccumulation, waste.

1. Introduction

Baqa'a is a residential area located in Ain Bal-Basha District, Balqa Governorate in northwest Jordan, which includes 16 districts area (Figure 1). This area is one of the hotspots affected by environmental pollution in Jordan. This due to many factors that are related to industrial, commercial, construction, agricultural activities and traffic load. This area included the largest refugee camps in Jordan with a high density of population. This in turn increases the pressure on infrastructure and soil uses in the region. In this context, the government is showing keen interest in the environment of the Baqa'a area to reduce pollution and thus the environmental risks that affect the population of the region through several practical and scientific measurement. The study area situated 640 m above sea level, on longitude 35° 48′ 30″ and 35° 53′ 00″ E and latitude 32° 03′ 00″ and 32° 03′ 00″ N. The study area embraces many types of small industries and farms producing various crops. The climate in the area is almost cold to moderate over a year (i.e. 7-33C°) with humidity of 50-70%, and average annual rainfall of 400 mm (Jordan Metrological Department, 2018). The area is located on a flat plain or as basin surrounding by high altitude area and it is considered as an aquifer for groundwater. Soil cover the topographical lows and pediment slopes, and together with calcrete obscures much of the bedrock. This study comes in the context of efforts to put the decision-maker in soil pollution by studying an assessment of the heavy metals in soil and their environmental impact. From geological point of view, the exposed rocks in the area are part of Jurassic- Cretaceous age. Structurally, the area covers the northeastern part of the Wadi Shu'ayb structure. Fluvial gravel, sand, silt and fine loess on hill slopes constitute Pleistocene sediments. Holocene to Recent alluvial and Wadi sediments consist of sorted clasts in a sand matrix and are being deposited and reworked by the present-day drainage. Soil cover the topographical lows and the pediment slopes and together with calcrete and carbonate obscures much of the bedrocks.

Heavy metals are extremely persistent in the environment and are non-biogradable and thus readily accumulate to toxic levels. 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). Determination of heavy metals in soil ecosystems has been noticed by many researchers, among them (Abrahim and Parker, 2008; Al Obaidy and Al Mashhadi, 2013; Asaah and Abimbola, 2006; Bambara et al., 2015; Stanley et al., 2014; Radojevic and Bashkin, 2006; Nada et al., 2019; Nowrouzi and Pourkhabbaz, 2014, Afrifa, et al., 2013). When the

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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). Most of these pollutants can be carried by rain and wind from a pollution source to a great distance (Stanley et al., 2014).

This study is aimed to focus and to asset the heavy metals levels contamination in surfaces soil of Baqa'a area and to determine their concentration and interconnection released in urban areas. Physicochemical tests have been carried out to characterize the main properties of the soil based on granulometric analysis (particle-size distribution), moisture content, pH, electrical conductivity (EC), total dissolved solids (TDS), Inductively coupled plasma (ICP) and X-Ray diffraction (XRD). Soil contamination was assessed using three indices including an index of geoaccumulation (I_{geo}), contamination factor (CF) and degree of contamination (C_{deg}).

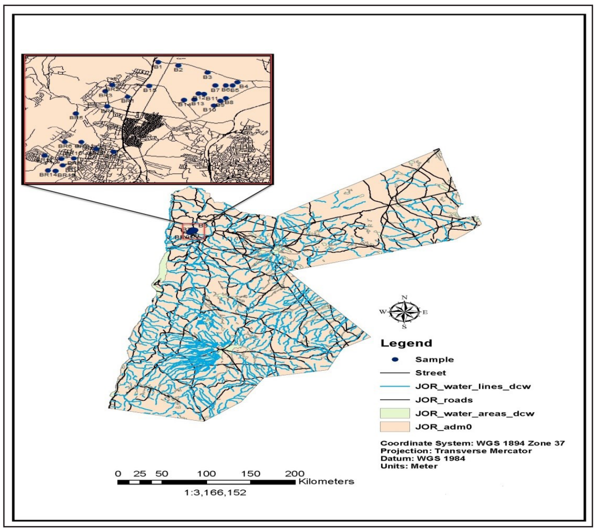

Figure 1. Location map of the study area.

2. Geology

The geology cropping out in the area is part of Jurassic - Cretaceous age (Sawariah and Barjous, 1993). The oldest exposed rocks in the area belong to the Azab Group (Jurassic) (Figure 2). The Azab group composed of mudstone, sandstone, dolomite and dolomitic limestone interbedded with silty dolomite and oolitic limestone. The lower cretaceous Kurnub Sandstone group (Aptian to early Cenomanian), rests unconformably on the Azab Group. Kurnub Sandstone overline by Ajlun Group, based marked by Na'ur Limestone Formation (Cenomanian) and consist of bituminous marly limestone, nodular in texture with fragments of gastropods and bivalves, intercalated with glauconitic marl. Na'ur Formation overlies by Fuhays Formation (Cenomanian) form gentle slopes. It consists of yellowish brown to olive-green marl intercalated with thin-bedded nodular limestone and marly limestone (Sawariah and Barjous, 1993).

The base of overlying Hummar Formation (Upper Cenomanian), is marked by a buff, massive marly limestone and micritic limestone, dolomitic limestone and dolomite intercalated with thin beds of marly limestone, marl and mudstone. The overlying Shu'ayb Formation (upper Cenomanian- Lower Turonian) consist of whitish-grey, thinly bedded chalky limestone and thinly bedded limestone, intercalated with buff-yellow marl. Massive to hard, buff dolomitic limestone marks the base of the overlying Wadi As Sir Limestone Formation (Turonian) (Sawariah and Barjous, 1993).

The overlying Wadi Umm Ghudran Formation (Coniacian-Santonian) is the basal unit of the overlying Belqa'a Group. The succeeding Amman Silicified Limestone Formation (Santonian-Campanian) is the youngest bedrock exposed in the study area. The formation composed of chert nodules, limestone, dolomitic limestone, marl, phosphatic chert, phosphate and apatite schist (Sawariah and Barjous, 1993).

Fluvial gravel, sand, silt and fine loess on hill slopes constitute Pleistocene Sediments, whereas thick soil up to 5 m in the Wadi and low topography of the Baqa'a basin. Holocene to Recent Alluvial and Wadi Sediments consist of sorted clasts in a sand matrix, clayey sand and clay are being deposited and reworked by the present-day drainage. Most of the soil can be considered as sandy loam to loamy sand.

Structurally, the area covers the northeastern part of the Wadi Shu'ayb structure. This structure is dominated by the northern extension of the NE-SW trending deformed belt (i.e. Wadi Shu'ayb structure), which consists of an echelon fold, monoclinal flexures and faults. The NNE-SSW trending Al Baqa'a asymmetrical anticline is 15 Km long and its width varies from 1 to 7 Km. This structure forms a negative geomorphological feature (i.e. depression) due to the high erodability of the Kurnub Group, which form the core, in contrast to the surrounding resistant Ajlun Group. The fault systems which are associated with the deformed belt are oriented NNE-SSE, SE-NW.

The topography reflects Neogene regional up-warping, folding and eastward beds tilting reflected on the terrain surface, accompanied by relative uplift in relation to block faulting west of Jordan Valley. The difference in the altitude is reflected in the westward direction of the river valleys. The drainage has rejuvenated during the tectonic phases, and a rapid incision into the main wadis has given rise to high relief with deep valleys and unstable slopes where mass movement takes place as landslides and debris flows (Sawariah and Barjous, 1993).

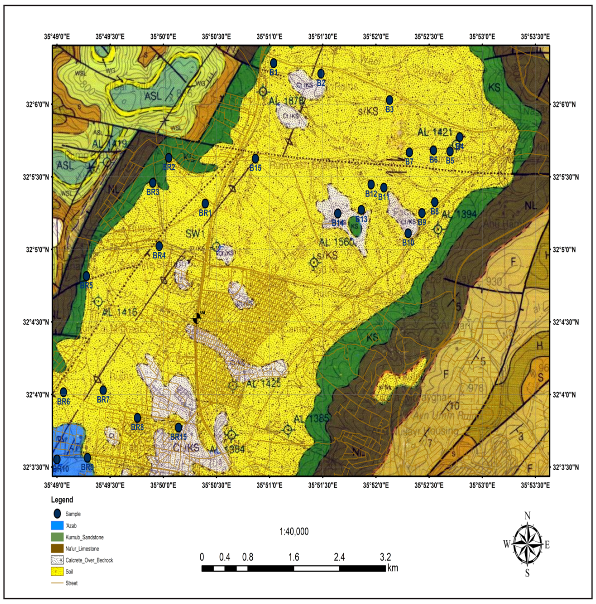

Figure 2. Geological map of the study area (modified after Sawariah and Barjous, 1993).

3. Materials and methods

3.1 The Soil Sampling

Thirty topsoil samples (0-20 depth cm) were collected from different localities of the study area with distance of samples from 0.500m up to 1 km and covered an area of about 20Km^2. ArcGIS " Geographic Information System" (version 10.2) was used to position the sampling sites with their attributes. For this purpose topographic map using coordinate system GCS WGS 1984 was prepared to locate the coordinates of the collected samples (Figure 3). The studied samples were selected during the winter season. The distance between samples differs and depend on the ease of access to the site and variability of the texture and the homogeneity of the soil. Three kilograms (3Kg) of each sample was collected with plastic tools and sorted into polyethylene bags. Standard methods were used for sample collection, preservation and analysis recorded by Ryan et al. (2001).

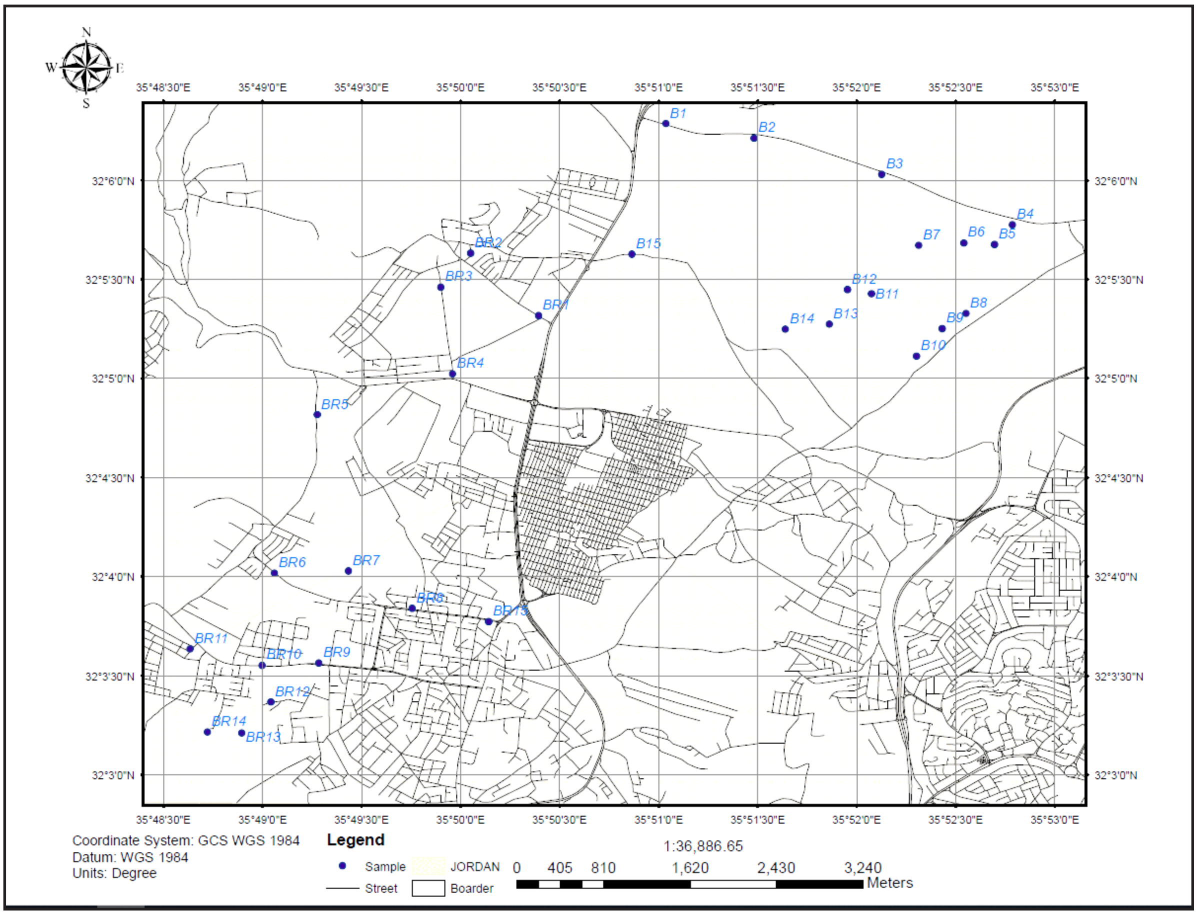

Figure 3. The map shows the sample location.

3.2 Granulometric Analysis

The studied samples were dried in the oven up to 100 C^o, then crushed and sieved through a 2 mm stainless sieve to remove debris. Sieve analysis has been carried out to determine the percentage of gravel, sand, and fine fraction using an ASTM sieve. About 100 g of soil sample was sieved at sieve No10, No 20 and No 200 prior to analysis. A hydrometer test was used to determine the percentage of silt and clay for representative samples (Table 1).

3.3 Physicochemical Methods

Soil texture and particle size distribution, moisture content, pH, EC and TDS were determined. Salinity is a measurement of all dissolved salts in water. It is usually measured indirectly and is derived from a conductivity reading using a conversion factor that would often be pre-programmed into the conductivity meter.

Salinity can affect the level of dissolved oxygen in the water. It is also called electrical conductivity (EC) which measures a substances ability to conduct an electrical current and this can be applied by using a conductivity meter. TDS, pH and EC parameters were determined by using the conductivity TDS meter (Model Hatch 44600). The procedure is done by mixing into a slurry with distilled or deionized water. Approximately 10 g of the air-dried sediments were suspended in 50 mL of deionized water and manually agitated for five minutes. The suspension was allowed to rest for about one hour with occasional shaking until pH, TDS and EC were determined (Table 1).

Inductively Coupled Plasma – Optical Emission Spectroscopy (ICP-OES) was used to determine the concentrations of heavy metals of Co, Cr, Cu, Mn, Ni, Pb, Zn, Cd and V. The samples were filtered by a membrane filter of a pore size of 0.45 µm before analyses using Standard Methods (APHA, 1995). Digestion solutions were measured for the total heavy metals using ICP-OES.

Selected samples were analyzed by XRD using 1 gram of a randomly oriented powder which put on a rotating sampler holder, and leveled with a glass slice to obtain a flat surface. XRD was also acquired using Zincite (ZnO) as internal standard.

Table 1. Grain size distribution and physical properties of the studied soil.

Site	Moisture	Sand	Silt	Clay	pH	TDS mg/l	EC 1500(µs/cm)
B1	17.6	83.07	15.50	1.43	8.54	106	275
B2	17.8	82.55	16.20	1.25	8.37	105	270
B3	17.2	82.95	15.70	1.35	7.70	103	265
B4	17.0	83.50	15.23	1.32	7.60	171	322
B5	16.5	80.30	18.40	1.30	8.22	140	205
B6	17.0	81.85	16.50	1.65	8.40	150	208
B7	17.3	82.74	15.70	1.56	8.40	155	206
B8	18.3	84.90	13.80	1.33	8.00	220	400
B9	17.5	83.95	14.50	1.55	8.65	200	399
B10	17.4	83.36	15.30	1.34	8.85	225	420
B11	17.3	83.99	14.78	1.23	8.90	226	427
B12	17.5	82.60	15.86	1.54	8.87	131	262
B13	16.9	87.20	11.50	1.31	8.37	230	460
B14	17.2	86.01	12.34	1.65	8.62	236	409
B15	17.6	85.13	13.53	1.34	8.62	110	144
BR1	16.8	86.13	12.33	1.54	7.40	220	480
BR2	16.7	83.22	15.34	1.44	8.35	225	481
BR3	16.7	84.70	13.45	1.85	8.39	75	150
BR4	16.5	83.96	14.70	1.34	8.26	76	151
BR5	16.2	83.01	15.65	1.34	8.56	78	144
BR6	16.5	85.24	13.33	1.43	8.39	77	156
BR7	16.9	82.32	15.80	1.88	8.26	80	154
BR8	16.3	81.32	17.34	1.34	8.34	86	150
BR9	17.0	82.67	16.90	1.33	8.39	88	148
BR10	17.3	83.36	14.77	1.87	8.59	89	188
BR11	16.6	85.11	13.44	1.45	8.32	86	210
BR12	16.3	86.33	12.34	1.33	7.59	78	189
BR13	16.9	87.01	11.54	1.45	8.35	88	166
BR14	16.8	87.11	11.56	1.33	7.57	89	123
BR15	16.9	87.20	11.58	1.37	8.60	90	156
Max	18.3	87.20	18.40	1.88	8.90	236	481
Min	16.2	81.32	11.50	1.23	7.40	75	123

3.4 Soil Contamination Assessment

The assessment of soil contamination was carried out. For this purpose, different indices have been applied to assess the heavy metal distribution and concentration. The indices of Geoaccumulation index (I_{geo}) and contamination factor (CF) were used to determine and define the contamination in sediments (Müller, 1969). A normalized indices approach for heavy element concentration is adopted in this study using World Uncontaminated Background Soil (Kabata-Pendias and Mukherjee, 2007), that compared to the average soil in the studied area as shown in Table 2.

3.4.1 Index of Geoaccumulation (Igeo)

The I_{geo} is calculated according to the method of Müller (1969) and Nowrouzi and Pourkhabbaz (2014). This index is calculated using the following mathematical relation:

$$I_{geo}= log2[\frac{Cn}{1.5Bn}] \quad (1)$$

Where C_n is the measurement of total concentration in soil metal n, and B_n is the background value for the metal n. Factor 1.5 is incorporated in relationship to accounting for possible variation in the background data due to lithologic effects.

Table 2. Salinity classes and relationship between $EC_{1:1}$ to ECe values.

	Degree of Salinity (Salinity Classes)					
	Non-Saline	Slightly Saline	Moderately Saline	Strongly Saline	Very Saline	Ration of EC1:1 to ECe
EC1:1 Method (Ds/m)						
Coarse to loamy sand	0-1.1	1.2-2.4	2.5-4.4	4.5-8.9	9.0+	0.56
Loamy fine sand to loam	0-1.2	1.3-2.4	2.5-4.7	4.8-9.4	9.5+	0.59
Silt loam to clay loam	0-1.3	1.4-2.5	2.6-5.0	5.1-10.0	10.1+	0.63
Silty clay loam to clay	0-1.4	1.5-2.8	2.9-5.7	5.8-11.4	11.5+	0.71
ECs Method (dS/m)						
All textures	0-2.0	2.1-4.0	4.1-8.0	8.1-16.0	16.1+	NA

3.4.2 Contamination Factor (CF) and Degree of Contamination (C_{deg})

Contamination factor was used to determine the contamination level of the sediments by applying the following equation:

$$CF = \frac{Cn}{Bn} \qquad (2)$$

Where Cn is the concentration of the heavy metal in the soil sample, and Bn is the background value for the same metal (Bambara et al., 2015 and Abrahim and Parker, 2008). The background concentration was calculated from the heavy metal concentration in unaffected soils (Kabata-Pendias and Mukherjee, 2007).

The degree of contamination (C_{deg}) was proposed by Hakanson (1980) as a generalized form and it can be calculated by the following equation:

$$C_{deg} = \Sigma\ (Cm/Bn)^I \qquad (3)$$

where i, represent the respective metals Co, Cr, Cu, Mn, Ni, Pb, Zn, Cd and V, while Cm is the measured metal concentration in the studied soil, and Bn is the background concentration value of metal concentration in unaffected soils (Kabata-Pendias and Mukherjee, 2007).

4. Results and discussion

4.1 Soil Physicochemical Properties

Soil texture and particle size distribution, moisture content, pH, EC and TDS were determined. The results are shown in Table 1. Particle-size distribution and soil texture classes showed that the soil is composed mainly of sand with silt and clay. The percentage of the sand varies between 81.32 and 87.20%, whereas the silt is between 11.50 and 18.40% and clay varies from 1.23 to 1.88%. Regarding these results, it can be noticed that most of the soil can be considered as sandy loam to loamy sand (Table 2).

Soil water affects the moisture content of the nature and amount of soluble materials, osmotic pressure and the pH of the soil solution (Paul, 2007). The current study showed a moisture content ranges from 16.2 to 18.3%. Insignificant differences with less than 1% were observed among the most studied sites (Table 1). It can be argued that lower pH corresponds with higher $[H^+]$, while higher pH is associated with lower $[H^+]$.

Measurement of pH of soil samples shows that some of them have pH higher than 8, while good soil ranges between 5.5-7. Results show that the soil pH varies from 7.40 to 8.90 (Table 1), with small significant differences ≤ of 0.6, that were observed among the studied sites. These results show that the studied soils are mostly in neutral to sub-alkaline conditions.

Results of the EC and TDS are related together and they increased. EC varies between 123 and 481(µs/cm), whereas the TDS varies between 75 and 235mg/l. EC and TDS measurements can vary greatly and are affected by several environmental factors including, climate, local biota (i.e. plants and animals), rock lithology and surficial geology, as well as human impacts on land. EC and TDS also are related to pH and their norms are within the type of most slightly to moderately saline for some samples as indicated in Table 2.

4.2 XRD Results

The soil samples were performed by using XRD. The results show that the major existing minerals quartz, while calcite, dolomite and kaolin are minor minerals (Figures 4, 5). These minerals are mainly related to the anthropologic processes and are part of the composition of the geological units surrounded the study area. The quartz is the dominant mineral in all tested samples and reached up to 95.53% by weight as indicated by granulometric analysis. Calcite and dolomite are present and most of these minerals considered as a main component of the limestone and dolomitic limestone rocks surrounding the area. Their presence could be explained also as a result of small leaching processes (Nada et al., 2019). Clay minerals also occur as minor minerals and could be explained by the chemical weathering of primary minerals as feldspar.

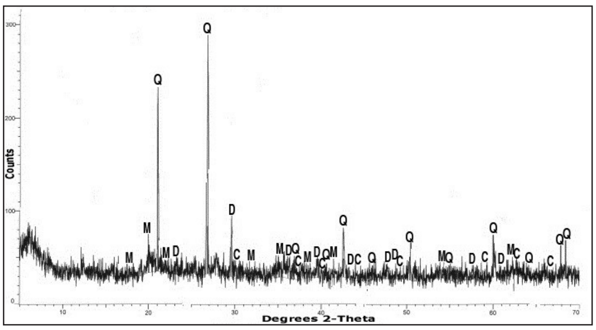

Figure 4. XRD of bulk sample from the study area (Q=Quartz; C=Calcite; D=Dolomite M=Montmorillonite).

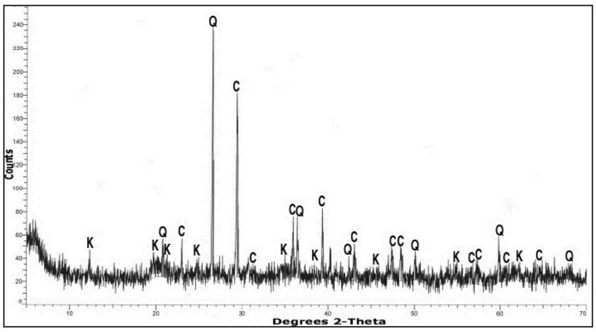

Figure 5. XRD of bulk sample from the study area (Q=Quartz; C=Calcite; D=Dolomite M=Montmorillonite).

4.3 Soil Metal Contamination

A normalized norm for heavy metals concentration, adopted in this study is based on the world uncontaminated soils used by Kabata-Pendias and Mukherjee (2007). The results and the norms of heavy metals are shown in Table 3. Nine heavy metals (Co, Cr, Cu, Mn, Ni, Pb, Zn, Cd and V) were determined in thirteen sites. As shown from the results, the average concentration of these metals is in the following sequence in (ppm): Co (15); Cr (182); Cu (27); Mn (737); Ni (90); Pb (10); Zn (87), Cd (0.10); and V (92). This allows for the arrangement of the heavy metals from the higher to lower mean content as follows: Mn > Cr >V >Ni >Zn > Cu > Co > Pb > Cd. The results show that the concentration of Cr, Co, Mn, Ni and Zn are higher in many samples, whereas the concentration of Cu, Pb, V and Cd are less than the norms. Small exceptions from the norms can be seen for some samples as in sample B1 for the heavy elements of Zn and Mn; sample BR4 and B11 for Co, Mn and Pb; BR13 and BR15 for Co, and BR11 with a high concentration of V. The soil is contaminated with Co, Cr, Mn, Ni and Zn that exceeding the standard levels in most of the sites, exception of this rule can be seen in some sites as indicated in B1, B3, B4, BR11, BR15. Sites B10, B12, B13 and B14 are contaminated with Mn that exceed 1000ppm. Site B14 represent the most contaminatedplace with Co, Cr, Mn, Ni, Zn and V. The values of these heavy metals in this site are twice the values of adopted norms. Most samples did not exceed the values approved in this study regarding the adopted norms. It can be argued that a high concentration of Co, Cr, Mn, Ni, Zn and V in some sites as indicated in sites B10, B12, B13 and B14 could be related to natural processes that include rock weathering and erosion, leaching and wind-blown dust. On the other hand, anthropogenic activities, including industrial, agricultural activity and motor vehicle traffic, are considered as one of the main sources of contamination that could be affected in some sites as seen clearly in site B14, and partially in other sites (B1, B3, B4, B10, BR 11, B12, B13, BR 15), that exceeds the adopted norms.

4.3.1 Index of Geoaccumulation (I_{geo})

The index of geoaccumulation (I_{geo}) for contamination levels in the soil have been taken after Rahman et al. (2012) and Odat (2015). It consists of seven grades from 0 to 6, ranging from uncontaminated to extremely contaminated (Table 4). The factor 1.5 incorporated in the relationship to account for possible variation in background data due to lithological effects. The calculated I_{geo} values are shown in Table 5. Compared to the average soil, the I_{geo} values indicated that the results reported uncontaminated soil ($I_{geo} \leq 0$ for Cu, Pb, V and Cd), uncontaminated to moderately contaminated soil (0 <Igeo<1 for Co and Mn, Zn, Ni). It can be noticed that there is an exception in some sites in I_{geo} values as for Zn, Pb, and Ni. At the site, BR9 Ni value (I_{geo}=2.95), that can be considered moderately/strongly contaminated; I_{geo} value for Cr inmost of the samples are uncontaminated to moderately contaminated and highly contaminated (2 <Igeo<3), as seen in BR9 (Cr I_{geo}=2.98).Contaminated/ moderately contaminated/highly contaminated in some sites, as reported in site BR9, that could be attributed to high traffic and industrial activities, in addition to anthropogenic effects such as excavated construction materials and randomly dumping of the wastes nearby the site.

Table 3. Results of the ICP and the norms of the average world soil.

No	sites	Co	Cr	Cu	Mn	Ni	Pb	Zn	Cd	V
1	B-1	11	139	21	486	65	6	57	0.1	79
2	B-2	16	146	26	688	82	8	78	0.1	94
3	B-3	13	133	24	547	63	6	66	0.1	79
4	B-4	13	141	25	577	66	6	67	0.1	74
5	B-5	17	151	25	686	73	8	74	0.1	84
6	B-6	17	166	32	699	83	8	89	0.1	87
7	B-7	15	170	26	652	82	8	73	0.1	84
8	B-8	15	162	25	655	78	9	72	0.1	83
9	B-9	16	173	26	680	83	10	77	0.1	88
10	B-10	17	142	30	760	76	10	105	0.1	92
11	B-11	18	156	34	789	90	11	103	0.1	96
12	B-12	15	152	32	680	87	8	111	0.1	99
13	B-13	20	150	32	777	89	10	89	0.1	105
14	B-14	17	185	34	694	106	12	103	0.1	97
15	B-15	15	166	28	565	81	7	75	0.1	87
16	BR-1	17	157	32	745	76	10	92	0.1	98
17	BR-2	17	195	32	709	111	8	103	0.1	102
18	BR-3	17	160	34	747	79	9	107	0.1	97
19	BR-4	10	337	23	342	161	7	79	0.1	50
20	BR-5	13	145	26	580	65	13	85	0.1	78
21	BR-6	18	154	26	718	80	11	80	0.1	98
22	BR-7	18	152	35	788	84	13	106	0.1	98
23	BR-8	23	166	24	815	70	12	80	0.1	83
24	BR-9	15	703	34	524	336	11	88	0.1	79
25	BR-10	15	151	29	1000	78	47	104	0.1	75
26	BR-11	8	168	21	921	83	4	72	0	112
27	BR-12	12	166	20	1201	83	6	73	0.1	120
28	BR-13	9	180	23	1288	77	6	80	0.1	108
29	BR-14	20	117	20	1283	52	1	125	0.1	158
30	BR-15	5	166	22	807	69	8	97	0.1	86
Average		15	182	27	737	90	10	87	0.10	92
Min		5	117	20	342	52	1	57	0.0	50
Max		20	703	35	1288	336	47	125	0.10	158
Range		5-20	117-703	20-35	342-1288	52-336	1-47	57-125	0-0.10	50-158
Norms		11.3	59.5	38.9	488	29	27	70	0.41	129

Table 4. I_{geo} accumulation index values (Rahman et al., 2012).

I_{geo} Class	I_{geo} value	Contaminated level
0	Igeo≤0	uncontaminated
1	0 <Igeo<1	Uncontaminated/moderately contaminated
2	1 <Igeo<2	moderately contaminated
3	2 <Igeo<3	Moderately/strongly contaminated
4	3<Igeo<4	Strongly contaminated
5	4 <Igeo<5	Strongly /extremely contaminated
6	5<Igeo<6	extremely contaminated

Table 5. I_{geo} accumulation index value of the heavy metals in the study area.

	Co	Cr	Cu	Mn	Ni	Pb	Zn	V	Cd
B-1	-0.38	0.64	-1.47	-0.59	0.58	2.75	-0.47	-1.29	-2.62
B-2	-0.08	0.71	-1.17	-0.09	0.91	2.34	-0.02	-1.04	-2.62
B-3	-0.38	0.58	-1.28	-0.42	0.53	2.75	-0.26	-1.29	-2.62
B-4	-0.38	0.66	-1.22	-0.34	0.60	2.75	-0.24	-1.39	-2.62
B-5	0.00	0.76	-1.22	-0.09	0.75	2.34	-0.10	-1.20	-2.62
B-6	0.00	0.90	-0.87	-0.07	0.93	2.34	0.17	-1.15	-2.62
B-7	-0.18	0.93	-1.17	-0.17	0.91	2.34	-0.11	-1.20	-2.62
B-8	-0.18	0.86	-1.22	-0.16	0.84	2.17	-0.13	-1.22	-2.62
B-9	-0.08	0.95	-1.17	-0.11	0.93	2.02	-0.04	-1.14	-2.62
B-10	0.00	0.67	-0.96	0.05	0.80	2.02	0.41	-1.07	-2.62
B-11	0.09	0.81	-0.78	0.11	1.05	1.88	0.38	-1.01	-2.62
B-12	-0.18	0.77	-0.87	-0.11	1.00	2.34	0.49	-0.97	-2.62
B-13	0.24	0.75	-0.91	0.09	1.03	2.02	0.17	-0.88	-2.62
B-14	0.00	1.05	-0.78	-0.08	1.28	1.75	0.38	-1.00	-2.62
B-15	-0.18	0.90	-1.06	-0.37	0.90	2.53	-0.08	-1.15	-2.62
BR-1	0.00	0.81	-0.87	0.04	0.80	2.02	0.22	-0.98	-2.62
BR-2	0.00	1.13	-0.87	-0.05	1.35	2.34	0.38	-0.92	-2.62
BR-3	0.00	0.84	-0.78	0.03	0.86	2.17	0.44	-1.00	-2.62
BR-4	-0.76	1.92	-1.34	-1.10	1.89	2.53	0.17	-1.95	-2.62
BR-5	-0.38	0.70	-1.17	-0.34	0.58	1.64	0.10	-1.31	-2.62
BR-6	0.09	0.79	-1.17	-0.03	0.88	1.88	0.02	-0.98	-2.62
BR-7	0.09	0.77	-0.74	0.11	0.95	1.64	0.42	-0.98	-2.62
BR-8	-0.38	0.90	-1.28	-0.50	0.69	1.75	0.02	-1.22	-2.62
BR-9	-0.18	2.98	-0.78	-0.51	2.95	1.88	0.15	-1.29	-2.62
BR-10	-0.18	0.76	-1.01	0.45	0.84	0.21	0.40	-1.37	-2.62
BR-11	-1.08	0.91	-1.47	0.33	0.93	3.34	-0.13	-0.79	-2.62
BR-12	-0.50	0.90	-1.54	0.71	0.93	2.75	-0.11	-0.69	-2.62
BR-13	-0.91	1.01	-1.34	0.82	0.82	2.75	0.02	-0.84	-2.62
BR-14	0.24	0.39	-1.54	0.81	0.26	5.34	0.66	-0.30	-2.62
BR-15	-1.76	0.90	-1.41	0.14	0.67	2.34	0.30	-1.17	-2.62

4.3.2 Contamination Factor (CF)

The contamination factor (CF) is used to determine the contamination grade of heavy metals in the studied soil. Soil contamination categories based on CF proposed in this study was taken from Afrifa et al. (2003) and Hakanson (1980), as shown in Table 6. The calculated contamination factor values are shown in Table 7.

Table 6. 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

The results of the CF index of heavy metals of the studied samples indicated low contamination to considerable contamination. The maximum CF was found in site BR9 with high values (CF=11.82) for Cr and CF=11.59 for Ni, whereas values of CF for Cr in the rest of the samples are from moderate to considerable contamination as indicated in sites BR4 (CF=5.66) for Cr, and CF=5.55 for Ni. The values of CF for the heavy elements in the rest of the studied samples can be considered as moderate contamination levels.

4.3.3 Contamination degree (C_{deg})

To facilitate pollution control, Hakanson (1980) proposed a diagnostic tool named 'degree of contamination' (C_{deg}) as shown in Table 7. It is aimed at providing a measure of the degree of overall contamination in surface layers in a particular core or sampling sites. It can be concluded that the value of C_{deg} for most heavy metals in the studied samples indicated moderate to a considerable degree of contamination (Table 8). Exception of this conclusion can be noticed for some sites as indicated in Site BR9 that shows a high degree of contamination C_{deg}= 29.18. This site indicated highly contaminated as approved by CF and I_{geo} values and this could be due to to anthropogenic effects such as dumping of the wastes.

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

C_{deg} value	Contamination level
C_d<6	Low degree of contamination
6<C_d<12	Moderate degree of contamination
12<C_d<24	Considerable degree of contamination
C_d> 24	High degree of contamination

Table 8. Contamination factor (CF) and Degree of contamination (Cdeg) of heavy metals in the study area.

	Co	Cr	Cu	Mn	Ni	Pb	Zn	V	Cd	Cdeg	Result
B-1	1.15	2.34	0.54	1.00	2.24	0.22	0.81	0.61	0.24	9.16	M
B-2	1.42	2.45	0.67	1.41	2.83	0.30	1.11	0.73	0.24	11.16	M
B-3	1.15	2.24	0.62	1.12	2.17	0.22	0.94	0.61	0.24	9.32	M
B-4	1.15	2.37	0.64	1.18	2.28	0.22	0.96	0.57	0.24	9.62	M
B-5	1.50	2.54	0.64	1.41	2.52	0.30	1.06	0.65	0.24	10.86	M
B-6	1.50	2.79	0.82	1.43	2.86	0.30	1.27	0.67	0.24	11.90	M
B-7	1.33	2.86	0.67	1.34	2.83	0.30	1.04	0.65	0.24	11.25	M
B-8	1.33	2.72	0.64	1.34	2.69	0.33	1.03	0.64	0.24	10.97	M
B-9	1.42	2.91	0.67	1.39	2.86	0.37	1.10	0.68	0.24	11.64	M
B-10	1.50	2.39	0.77	1.56	2.62	0.37	1.50	0.71	0.24	11.67	M
B-11	1.59	2.62	0.87	1.62	3.10	0.41	1.47	0.74	0.24	12.68	CM
B-12	1.33	2.55	0.82	1.39	3.00	0.30	1.59	0.77	0.24	11.99	M
B-13	1.77	2.52	0.80	1.59	3.07	0.37	1.27	0.81	0.24	12.45	CM
B-14	1.50	3.11	0.87	1.42	3.66	0.44	1.47	0.75	0.24	13.48	MC
B-15	1.33	2.79	0.72	1.16	2.79	0.26	1.07	0.67	0.24	11.04	M
BR-1	1.50	2.64	0.82	1.55	2.62	0.37	1.31	0.76	0.24	11.82	M
BR-2	1.50	3.28	0.82	1.45	3.83	0.30	1.47	0.79	0.24	13.69	MC
BR-3	1.50	2.69	0.87	1.53	2.72	0.33	1.53	0.75	0.24	12.18	CM
BR-4	0.88	5.66	0.59	0.70	5.55	0.26	1.27	0.39	0.24	15.55	CM
BR-5	1.15	2.44	0.67	1.19	2.24	0.48	1.21	0.60	0.24	10.23	M
BR-6	1.59	2.59	0.67	1.47	2.76	0.41	1.14	0.76	0.24	11.63	M
BR-7	1.59	2.55	0.90	1.61	2.90	0.48	1.51	0.76	0.24	12.56	C
BR-8	1.15	2.79	0.62	1.06	2.41	0.44	1.14	0.64	0.24	10.51	M
BR-9	1.33	11.82	0.87	1.05	11.59	0.41	1.26	0.61	0.24	29.18	C
BR-10	1.33	2.54	0.75	2.05	2.69	1.74	1.49	0.58	0.24	13.40	CM
BR-11	0.71	2.82	0.54	1.89	2.86	0.15	1.03	0.87	0.24	11.11	M
BR-12	1.06	2.79	0.51	2.46	2.86	0.22	1.04	0.93	0.24	12.13	CM
BR-13	0.80	3.03	0.59	2.64	2.66	0.22	1.14	0.84	0.24	12.15	CM
BR-14	1.77	1.97	0.51	2.63	1.79	0.04	1.79	1.22	0.24	11.96	M
BR-15	0.44	2.79	0.57	1.65	2.38	0.30	1.39	0.67	0.24	10.42	M

M: Moderate; CM: Considerable Moderate; C: Considerable; MC: Moderate Considerable

5. Conclusions

The study area is one of the hotspots affected by environmental pollution in Jordan. This is due to many factors that are related to industrial, commercial, agricultural activities and traffic load. The study objective was to determine the level of contamination of heavy metals in the soil and to indicate their potential sources of origin. The area is located on a flat plain represented by a depression surrounding by elevated areas and it is considered as an aquifer for groundwater. Samples were analyzed using granulometric analysis, pH, electrical conductivity (EC), Total dissolved solid (TDS), Inductive coupled plasma (ICP) and X-ray diffraction (XRD). Soil contamination was assessed using three indices including the index of geoaccumulation (I_{geo}), a contamination factor (CF) and degree of contamination (C_{deg}).

The geology of the study affected by the high deformation of the rocks and the processes of weathering, erosion and leaching that had a very strong effect on soil deposition. Soil cover topographical lows and the pediment slopes, together with calcrete obscures much of the bedrock. Particle-size distribution and soil texture classes showed that the soil composed mainly of sand with silt and clay. The studied soil can be considered as sandy loam to loamy sand. The characteristics of quality sediment show that the soil has a pH ranging from 7.80 and 8.90, which slightly neutral to subalkaline. EC ranged from 123 to 481 (μs/cm), while TDS vary from 75 to 235 mg/l. EC and TDS are affected by different environmental factors that are related to climate, bedrock and surficial geology, as well as human activities.

Quartz is the dominant mineral identified by XRD, while calcite, dolomite and kaolinite are secondary minerals. The presence of these minerals are related to the anthropologic processes and are part of the composition of the geological units in the area.

Results of heavy metals indicated by ICP show the following concentration in (ppm): Co (15); Cr (182); Cu (27); Mn (737); Ni (90); Pb (10); Zn (87), Cd (0.10); and V (92). This allows an arrangement of the metals in the following sequence: Mn > Cr > V >Ni > Zn > Cu > Co > Pb > Cd. The concentration of Cr, Co, Mn, Ni and Zn are higher in most samples, whereas the concentration of Cu, Pb, V and Cd are less than the norms of average.

The I_{geo} values indicated that the results reported uncontaminated soil ($I_{geo} \leq 0$ for Cu, Pb, V and Cd), uncontaminated to moderately contaminated soil (0<1geo<1) for Co and Mn, Zn, Ni. It can be noticed that there is an exception in some sites for I_{geo} values for Zn, Pb, and Ni.

CF index of heavy metals indicating low contamination to considerable contamination. This can be seen in site BR9 with high values (CF=11.82) for Cr and Ni (CF=11.59), while CF in some sites as BR4 (CF=5.66) for Cr and (CF=5.55) for Ni. It can be noticed that CF values in the rest of the studied samples can be considered at moderate contamination levels.

It can be concluded that the value of C_{deg} for most of the heavy metals in the studied samples indicated a moderate to a considerable degree of contamination. Exception of this conclusion can be noticed for some sites as indicated in Site BR9, which shows a high degree of contamination (C_{deg}= 29.18). This site indicated also highly contaminated as approved by CF and I_{geo} values. This conclusion could be due to anthropogenic effects such as dumping of the wastes in this area and industrial activities that increased the level of contamination.

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