Anadolu Orman Araştırmaları Dergisi
Anatolian Journal of Forest Research
http://dergipark.gov.tr/ajfr

Spatial Distribution of Some Toxic Elements in Some Urban Soils of Çankırı, Turkey¤

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ARTICLE INFO
Received: November 26, 2018
Accepted : December 17, 2018
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¤ This paper was presented in 9th International Soil Science Congress on "The Soul of Soil and Civilization" 14-16 October, 2014, Antalya, Turkey.

ABSTRACT

Urban soils in Çankırı city have a high potential impact on water and air quality in residential areas. High heavy metal contents of these soils may pose considerable risk to the urban residences as most of the soils are bare due to inappropriate conditions for plant growth. We evaluated vertical and horizontal distribution of heavy metals concentrations in soils along the highway crossing the city in NE to SW direction. Each of ten sampling sites was sampled at five soil depths (0-2,5; 2,5-7,5; 7,5-12,5;12,5-17,5; 17,5-30 cm). The concentrations of heavy metals were measured using an Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Means of heavy metal concentrations were Fe>Mg>Mn>Ni>Cr>Zn>Cu>Ca>Co> Pb>Na>K>Cd>Hg. Concentrations of Fe and Mg were higher than critical values set for their maximum threshold soil concentrations for human health. The spatial distributions of Mg, Cr, Mn, Fe, Co, Ni, K, and Ca concentrations gradually decreased from NE to SW. Concentrations of Hg was far greater in the NE-half than SW-half, while concentration of Na was far greater in the SW-half of the transect than its NE- half. Concentrations of Cd, Cu, and Pb showed patchy distribution, and greater Zn concentrations occurred at both ends of the transect compared to values closer to city center. No significant correlation was found between pH and concentration of any of the studied heavy metals. In general, horizontal variation of heavy metals were greater compared to their vertical variation. Concentration of Mg was far greater than that of Ca and this was attributed to the parent material of the soils, which comprises considerable amount of serpentine. Potential contamination indices of the soil samples were: Fe, Mg, Na, Ca, K, Cr, Ni, Co, Cu, Mn, Zn, Cd, Pb, and Hg in decreasing order. Integrated pollution index showed that Fe and Mg concentrations of all samples were greater than 1, suggesting that these heavy metals have a significant risk on health of city residents.

Keywords: Çankırı, Heavy metals, Public health, Serpentine, Sodic urban soils.

Bazı Çankırı Şehir Topraklarında Toksik Elementlerin Uzaysal Değişimi

ÖZ

Çankırı şehir toprakları, şehirdeki hava ve su üzerinde önemli potansiyel kirletici etkiye sahiptir. Bu topraklar, içerdikleri yüksek miktarlardaki ağır metaller ve yüzeylerinin çıplak olması nedeniyle şehir sakinleri üzerinde önemli sağlık riski taşımaktadır. Bu çalışmada, şehri kuzeydoğu ve güneybatı yönünde ikiye ayırmakta olan şehirlerarası ana yol boyunca toprakların ağır metal içeriklerinin dikey ve yatay yöndeki değişimi incelenmiştir.

Bu bağlamda hat belirlenen 10 noktadan derinlik esasına göre (0-2,5; 2,5-7,5; 7,5-12,5;12,5-17,5; 17,5-30 cm) alınan toprak örnekleri Inductively Coupled Plasma (ICP-MS) kullanılarak ağır metaller için analiz edilmiştir. Sonuçlar ortalamaların Fe>Mg>Mn>Ni>Cr>Zn>Cu>Ca>Co> Pb>Na>K>Cd>Hg şeklinde olduğunu göstermiştir. Mg, Cr, Mn, Fe, Co, Ni, K ve Ca konsantrasyonu kuzey batından güneydoğuya doğru azalan bir seyir göstermiştir. Cıva konsantrasyonu hattın kuzeydoğu yarısında, güneybatı yarısına nazaran daha yüksek bulunurken; Na içeriğinin güney batı kısmında kuzey doğu kısmına nazaran çok daha yüksek olduğu belirlenmiştir. Kadmiyum, Cu ve Pb

Citation:
Erşahin, S., Karahan, G., Gül, E., Sünal, S., Dikmen, E., Bilgili, B.C., 2018. Spatial Distribution of Some Toxic Elements in Some Urban Soils of Çankırı, Turkey. Anadolu Orman Araştırmaları Dergisi 4(2): 133-143.

konsantrasyonu yamalı/parçalı (patchy) bir dağılım göstermiş, Zn içeriği ise hattın uçlarına yakın bölgelerde merkeze göre çok daha yüksek değerler almıştır. Toprakların pH değerleri ile ağır metal konsantrasyonları arasında önemli bir ilişki çıkmamıştır. Genellikle, ağır metal konsantrasyonları dikey yöne nazaran yatay yönde daha yüksek değişkenlik göstermiştir. Düşük Ca/Mg oranı, bazı toprakların ana materyalinin önemli ölçüde serpantin içerdiğini göstermektedir. Toprakların potansiyel kirlenme indislerinin azalan yönde Fe, Mg, Na, Ca, K, Cr, Ni, Co, Cu, Mn, Zn, Cd, Pb ve Hg şeklinde olduğu belirlenmiştir. Entegre kirlilik riski Fe ve Mg diğerlerinin 1'den büyük olması nedeniyle bu metallerin şehirdeki insanların sağlığı üzerine önemli risk oluşturduğunu göstermektedir.

Anahtar kelimeler: Çankırı, Ağır metaller, Halk sağlığı, Serpantin, Sodik şehir toprakları

1. Introduction

High concentrations of heavy metals in urban soils often pose critical risks to public health especially in developing countries where urbanization, industrialization, and rapid population take place concurrently (Odoi et al., 2011). Each of those heavy metals manifests its unique human health concern, which becomes critical over a specified concentration. The origin and source of those metals can be highly different. For example, Pb, Cu, and Zn are more anthropogenic origin (Bilos et al., 2001), while Ni, Cd, and As are mainly terrestrial origin. Number of studies has been conducted on distribution of heavy metals around the world. Wei and Yang (2010) reported that concentrations of Cr, Ni, Cu, Pb, Zn, As, Hg and Cd were higher in urban soils and road dusts than their background values in over 25 cities across China. Vince et al. (2014) reported that Ba, Cd, Cu, Pb and Zn accumulated in the soils of Berehove, a small city in West-Ukraine, primarily resulted from anthropogenic activity.

The principal sources of elevated concentrations of heavy metals in urban soils are traffic, industrial activity, and household and industrial (toxic) wastes (Vince et al., 2014). Therefore, the studies regarding the heavy metal contamination of urban soils focus mainly on the large industrial centers and metropolises (Vince et al., 2014). On the other hand, geochemical quality of urban soils is a significant measure of a safe environment (Salonen and Korkka-Niemi, 2007). Large number of studies (Salonen and Korkka-Niemi, 2007) showed that the urban soil generally have greater concentrations of Pb, Cu, Zn, Hg, V, Ni and Mn than corresponding background samples.

Even in small towns, significant heavy metal pollution can be possible due to various human activities, such as shipyards, traffic, and industry (Salonen and Korkka-Niemi, 2007). In addition, geological factors can be major controls on the distribution of metals in some cases.

According to Jung (2001) and Park et al. (2006) heavy metals are released into the environment by both anthropogenic and natural sources. Heavy metals occur in almost all soils naturally, but their concentrations and impact in soil can be influenced by many factors (Facchinelli et al. 2001), such as anthropogenic activities such as industry, mining, and agriculture), climate, and parent material. According to studies, we can explain the anthropogenic sources of heavy metals into three categories. These are urban and natural elements, and elements of a mixed origin (Miguel et al. 1997). Motor vehicles, industry, and weathered materials are mainly sources of heavy metals in the urban area (Douay et al. 2007). Wei and Yang (2010) reported that anthropogenic sources of heavy metals in environment include traffic emission (vehicle exhaust particles, tire wear particles, weathered street surface particles, brake lining wear particles), industrial emission (power plants, coal combustion, metallurgical industry, auto repair shop, chemical plant, etc.), domestic emission, weathering of building and pavement surface, atmospheric deposits etc. in urban soils.

The parent material also largely influences contents of heavy metals in many soil types, with concentration sometimes exceeding the critical values (Palumbo et al., 2000; Romic and Romic, 2003; Salonen and Korkka-Niemi, 2007). Heavy metals are found in soils derived from different types of parent material. The natural amounts and compositions of the heavy metals are closely related to their concentrations and compositions in the parent materials. For instance, soils derived from serpentine, are generally rich in Mg and Ni. The ratio of concentration in soil to parent materials may be affected by soil forming factors (climate, topography, and vegetation) and processes (translocation, transformation, and transportation).

Brady and Weil (2011) reported that the physical, chemical, and biological properties of soils affect the mobility and toxicity of these heavy metals to environment. The mobility of each heavy metal is specific depending on its chemistry (chemical speciation) in soil aqua system and reaction (adsorption-desorption) to soil surfaces. For example soils poor in organic matter content, are prone to release heavy metals. Because, organic matter have a profound sorption capacity of the heavy metals (Sposito, 2008) and in soils with lower pH, the risk of heavy metal toxicity is greater as cation exchange sites of the soil particles are invaded by H^+ (Brady and Weil, 2011).

Sodic soils are characterized by their pH>8.5, EC<4 dS m^{-1} and exchangeable sodium percentage >15. These soils are known with their poor soil physical properties such as extremely low water infiltration and percolation and extremely poor soil aggregate stability. These soils become extremely hard when they dry, and sticky and impermeable when they wet. Soil sodicity is generally caused by irrigation of agricultural lands. However, soils derived from high sodium bearing deposits and rocks in arid, semi-arid, and semi humid climates can be highly sodic depending on physical and chemical properties of parent material. The soils of study area are derived from sodic lacustrine deposits. Their high clay content and pH may immobilize the heavy metals. However, since these soils are completely bare due to their poor physical and chemical properties, they are highly prone to be transported by wind to adjacent city parks, streets, bazaars, and so on, where they cause significant health problems.

Akyıldız and Karataş (2018) investigated heavy metal pollution in the Adana urban soils. They found widely above standarts values for Ni, As, Cr, and Al. They noted that these results related with geological and environmental factors. Besides geological origin, industrial and household origin heavy metal pollution has become serious problem in Çankırı urban soils. However, there is no literature on the spatial distribution pattern and contamination levels of those heavy metals in soil of Çankırı city. The aim of this study was to assess the vertical and horizontal distribution and contamination levels of the heavy metals (Fe, Mg, Mn, Ni, Cr, Zn, Cu, Ca, Co, Pb, Na, K, Cd, Hg) and the potential ecological risk of heavy metal pollutants in urban soils of Çankırı city.

2. Material and methods

2.1. Study area

This study was carried out in city of Çankırı, with a population of 72.000 located at 40 º 30' 41 º North latitude and 32 º 30' 34 º East longitudes between Kızılırmak and the main basins of the West Black Sea in the north of Central Anatolia Region of Turkey (Fig. 1). The city is 723 m above sea level. The climate in the region is semi-arid and annual temperature, humidity, and rainfall is 11 ºC, 60 %, and 418 mm, respectively (Anonymous, 2017). Çankırı is covered with bare mountains and plateaus generally, and soils of city are under threat from soil erosion.

2.2. Soil sampling and analysis

Soil samples were taken from 10 sampling sites on a transect along the highway crossing the Çankırı city in NE to SW direction at a distance of approximately 6 km. Each sampling site was sampled at five different soil depths (0-2.5; 2.5-7.5; 7.5- 12.5; 12.5-17.5; 17.5-30 cm). The sampling sites were chosen at localities where red colored soils dominate. The soil samples were air dried in laboratory, screened through 2 mm steel sieve, and stored in small self-sealing plastic bags. Some information on sampling sites is given in Table 1.

Table 1 Traffic and population loads and land uses of the sampling sites.

Sampling No	Sampling Site	Traffic load	Population load	Land uses
S1	Correctional center	Medium	Sparse	RA
S2	Correctional center	Medium	Sparse	RA
S3	Correctional center	Medium	Sparse	RA
S4	Correctional center	Medium	Sparse	RA
S5	Student dormitory	Heavy	Medium	RA
S6	Student dormitory	Heavy	Medium	RA
S7	Locomotive storage	Heavy	Sparse	IA
S8	Rail factory	Heavy	Sparse	IA
S9	Rail factory	Heavy	Sparse	IA
S10	Gas station	Heavy	Medium	CA

IA: Industrial area, RA: Residential area, CA: Commercial area

For ICP-MS analysis (Agilent 7700 series), 0.5 g of a soil sample was digested in an aqua regia with 8 ml (1:3 HNO: HCl; 1/4 nitric acid, 37%, 3/4 hydrochloric acid, 65%) and dried at 120 ^oC. Then, HNO_3 (10 ml, 0.5 M) was added to the samples. After filtered through blue band, residue was washed with 10 ml of 0.5 molar HNO_3, and completed with ultrapure water to 1000 ml. The filtrate was completed with ultrapure water to 50 ml. Finally, the total concentrations of Mg, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, Hg, Pb, and Na were measured with an ICP-MS. Soil particle–size distribution (Gee and Bauder, 1986), aggregate stability index (Kemper and Rosenau, 1986), pH and EC (McLean, 1982), soil organic matter content (Nelson and Sommers, 1982), and $CaCO_3$ (McLean, 1982) were determined in soil samples. Vertical and horizontal distributions of studied heavy metals were mapped by computer program the GS[+] (Robertson, 2001).

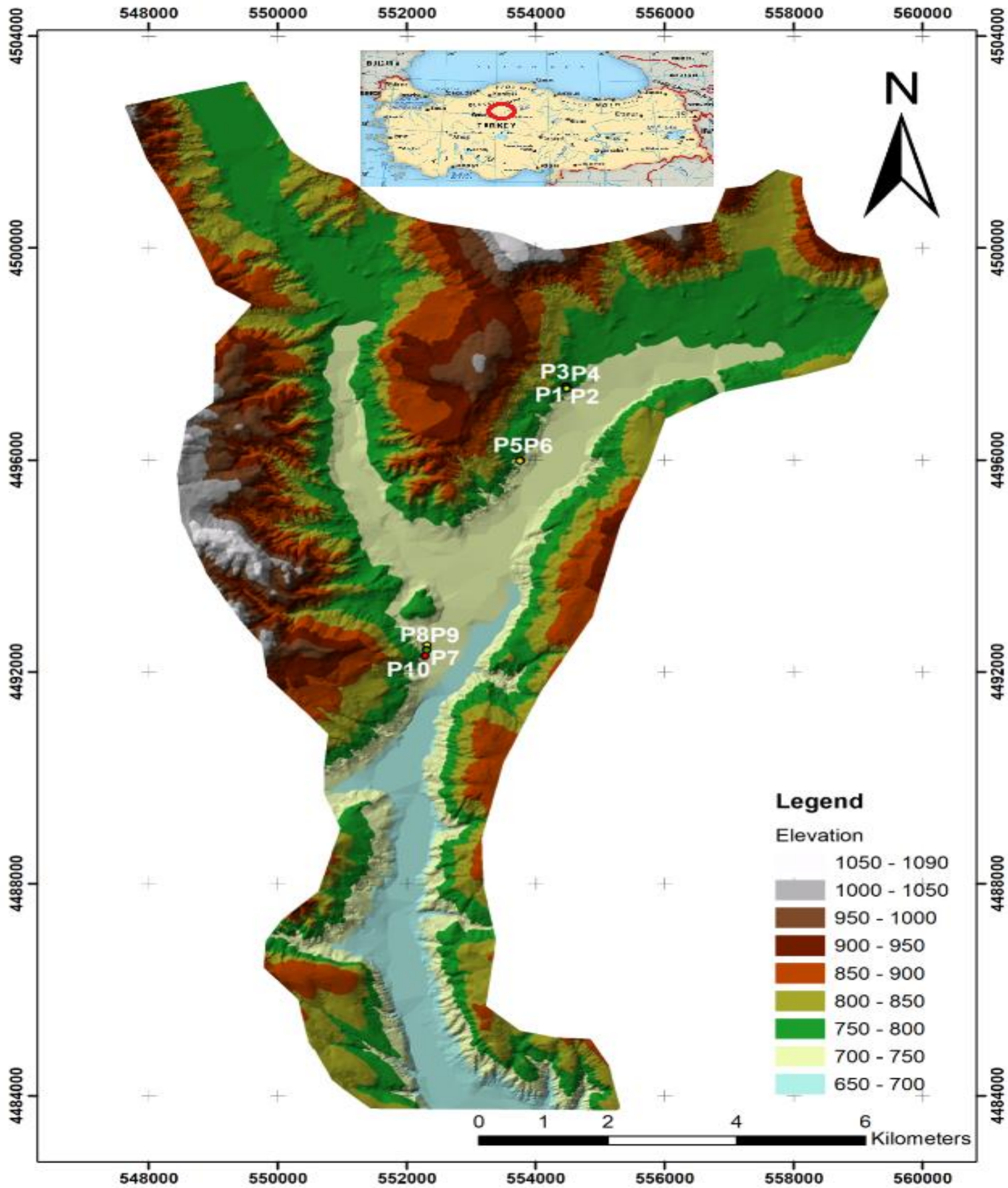

Figure 1 Location of the study area and sampling points (P1, P2, P3, P4: Correctional center; P5, P6: Student dormitory; P7: Locamative storage, P8, P9: Rail factory, P10: Gas station).

3. Results and discussion

3.1 Contamination levels of heavy metals

The concentrations of metals (Mg, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, Hg, Pb, and Na) in urban soils of Cankırı city were showed in Table 2. The soils are clay with a pH>8.5, EC <4 dS m^{-1}, and have very low aggregate stability (Table 2). Contrary to clay content, sand content had a highly negatively skewed distribution. The greatest variation occurred for EC and lowest for pH. These results are compatible to majority of the data reported by others. The aggregate stability is very low and this explains the low hydraulic conductivity of these soils, which results in observed micro landslides at sloping sites under snowmelt and rainfalls. Descriptive statistics of soil heavy metal contents in studied soils were given in Table 3.

Concentrations of Mg and Fe are greater than their critical values (Table 3). According to Webster (2002), distribution of Mg was slightly and of Fe was strongly left skewed. Greatest variation occurred for Cu and lowest for Zn. The variations for heavy metals were generally high. Considerably high right skewed distribution occurred for Cu, Cd, and Pb, indicating that some extremely high values of these metals occurred in some locations. However, their maximum values indicate these metals do not pose any risks for public health as they are far below their critical thresholds. In general, the metals with greater variation tended to distribute non-normally.

Table 2 Descriptive statistics of some physical and chemical properties of the study soils (N =50).

Soil Properties	Max.	Min.	Mean	S.D.	Skewness	Kurtosis	CV %
Sand, %	50.00	6.00	10.80	6.24	5.22	32.68	57.00
Silt, %	24.00	4.00	12.40	3.86	0.26	-0.31	32.00
Clay, %	88.00	42.00	76.82	6.98	-2.41	11.68	9.10
AS (%)	0.14	0.004	0.06	0.04	-0.16	-1.15	62.50
Salt (%)	0.26	0.01	0.07	0.06	1.65	2.11	90.70
pH	10.10	8.90	9.80	0.27	-1.42	2.07	2.80
OM, %	2.02	0.47	1.14	0.46	0.36	-0.75	40.40
$CaCO_3$, %	22.23	4.29	13.76	2.98	-0.52	2.92	21.60
EC(dS/m)	4.53	0.27	1.17	0.98	1.92	3.50	84.10

Max: Maximum, Min: Minimum, CV: Coefficient of variation, SD: Standard deviation, AS: Aggregate stability, OM:Organic matter, EC: Electrical conductivity

The maximum values of sand and silt content were found in first depth (0-2.5 cm) of 1. sampling point (Correctional center). However, the minimum sand content was found in fourth depth (2.5-7.5 cm) of 1. sampling point and minimum silt content was found in fifth depth (17.5-30 cm) of 4. sampling point (Railway factory). In addition, organic matter content of soils showed maximum values in 2.,3.,4., and 5. depths of 1. sampling point (correctional center). The $CaCO_3$ content also showed maximum value in fifth depth (17.5-30 cm) of 1. sampling point. The minimum values of organic matter content were found in third and fifth depths (7.5-12.5 and 17.5-30 cm) of 9. sampling point (Rail factory) and first depht of 10. sampling point (Gas station). The minimum value of $CaCO_3$ content was found in fourth depth (12.5-17.5 cm) of 8. sampling point (Rail factory).

The maximum value of soil clay content was found in fourth depth (12.5-17.5 cm) of 10. sampling point (Gas station) and the minimum value was found in fifth depth (17.5-30 cm) of 4. sampling point (Railway factory). Moreover, soil pH values showed maximum values in all depths of 10. sampling point (Gas station). The minimum value of soil pH was found in fifth depth (17.5-30 cm) of 2. sampling point (Student dormitory). Related with soil electrical conductivity, the maximum value was found in fifth depth (17.5-30 cm) of 9. sampling point (Rail factory). The minimum value of EC was found in first depth (0-2.5 cm) of 5. sampling point (Student dormitory).

In general, the maximum values of soil properties were found mostly at the all depths of the 1. and 10. sampling points (Correctional center and Gas station), while the minimum values were seen at all depths of all samples.

Size of contaminated site, concentrations and type, and source of heavy metals are important factors to control of soil pollution in contaminated areas (Markus and McBratney 2001; McGrath *et al.* 2004; Luo *et al.*2007). The normalized pollution severity (NPS) value for the contamination level of the metals was calculated by Eq. (1).

$$NPS = \frac{C}{C_t} \tag{1}$$

where C is the concentration of metal in environment, C_t is the threshold value for the metal.

A NPS value greater than 1 indicates high risk of the element to the public health. The NPS-values of urban soils of Cankırı was presented in Fig. 2 and metals with the highest NPS value and sampling zones are presented in Fig. 3.

Table 3 Descriptive statistics of soil heavy metal contents in studied soils (N=50).

Metals (mg kg^{-1})	Max.	Min.	Mean	SD	Skewness	Kurtosis	CV%
Mg	1399	308	840.7	265	-0.17	-0.42	31.50
Cr	73.13	1.60	12.14	24.41	1.60	0.72	2.00
Mn	66.10	15.52	35.75	12.25	0.61	-0.10	34.20
Fe	1511.91	452.50	1122.6	285.90	-1.07	0.44	25.40
Co	1.94	0.37	1.12	0.318	-0.16	0.23	28.40
Ni	12.89	2.91	9.03	2.62	-0.40	-0.81	29.00
Cu	15.17	0.46	1.94	2.10	5.47	-0.01	108.30
Zn	5.51	1.05	2.85	0.73	-0.01	3.59	25.70
Cd	0.37	0.003	0.027	0.06	5.25	31.68	200.40
Hg	0.04	0.001	0.01	0.01	2.03	4.76	105.90
Pb	5.10	0.39	0.95	0.82	3.76	15.65	86.80
Na	0.37	0.003	0.13	0.08	0.60	-0.22	63.30
K	0.12	0.03	0.08	0.02	-0.53	-0.05	28.30
Ca	2.19	0.62	1.44	0.39	-0.37	-0.34	27.10
Ca/Mg	2.52	1.35	1.76	0.26	0.72	0.51	14.80

Max: Maximum, Min: Minimum, SD: Standard deviation, CV: Coefficient of variation

The maximum value of Fe content was found in second depth (2.5-7.5 cm) of 9. sampling point (Railway factory). The minumum Fe content was found in second depth (2.5-7.5 cm) of 8. sampling point (also Railway factory). Moreover, the maximum value of Mg content was found in fifth depth (17.5-30 cm) of 1. sampling point (Correctional center). However, the minimum Mg content was found in in second depth (2.5-7.5 cm) of 6. sampling point (Student dormitory).

The Mean Normalized Pollution Severity (NPS_s) of elements in soil samples was given in Figure 2 and Normalized Pollution Severity (NPS) of Na, Mg, and Fe concentrations was given in Figure 3.

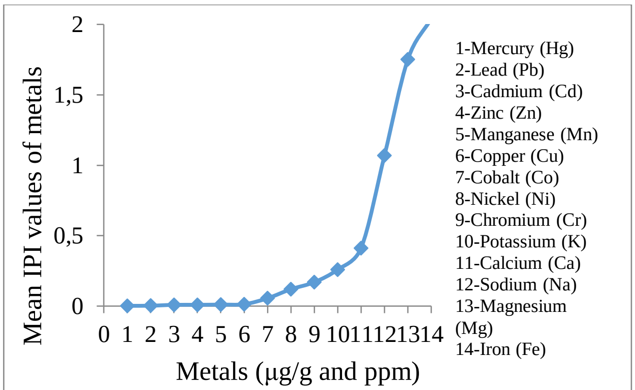

Figure 2 Mean normalized pollution severity (NPS) of metals in sampling points.

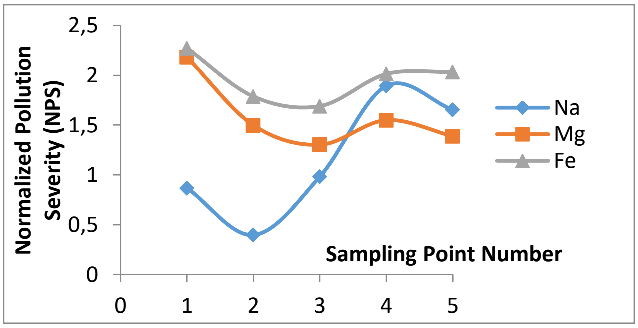

Fig. 3. Normalized pollution severity (NPS) of Na, Mg, and Fe concentrations at 1: Correction center, 2: Student dormitory, 3: Railway, 4: Rail factory, 5: Gas station.

The NPS_s of elements in soil samples ranged from 8.10^{-4} to 2.9. Figure 2 shows that the study soils are highly contaminated by Fe and moderately contaminated by Mg and Na. The maximum NPS value for Fe was 2.75, for Mg 2.92, and for Na 2.96. This indicates that the urban soils in the Çankırı city have been significantly impacted by these three metals (Fig. 3). It is highly difficult to comment on the source for Fe since it would be anthropogenic (mainly industrial) as well as geological. However, the high concentrations of Mg and Na could be mainly geological since the soils are derived from mostly serpentine and lacustrine originated sodic clay deposits.

3.2 Spatial distribution of metals

Spatial distribution of metal concentrations is a useful aid to assess the possible source of enrichment and determine spot sources of high metal concentration (Burgos *et al.*, 2008; Li *et al.*, 2008).

Surface maps for vertical and horizontal distribution of studied heavy metals Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb, and Zn are given in Fig.4.

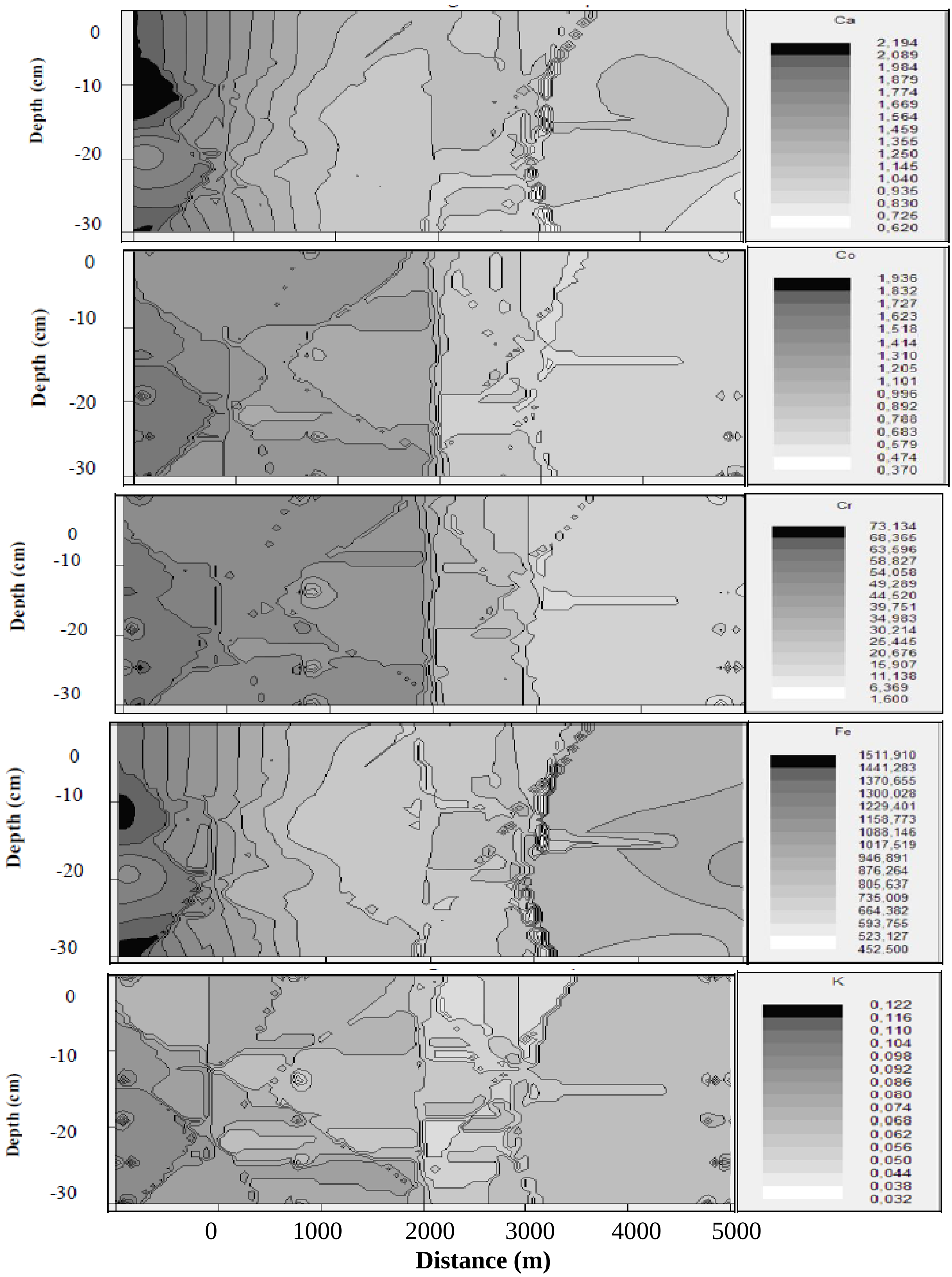

Fig. 4. Horizontal and vertical distribution of metal concentrations (μg/g) along the transect.

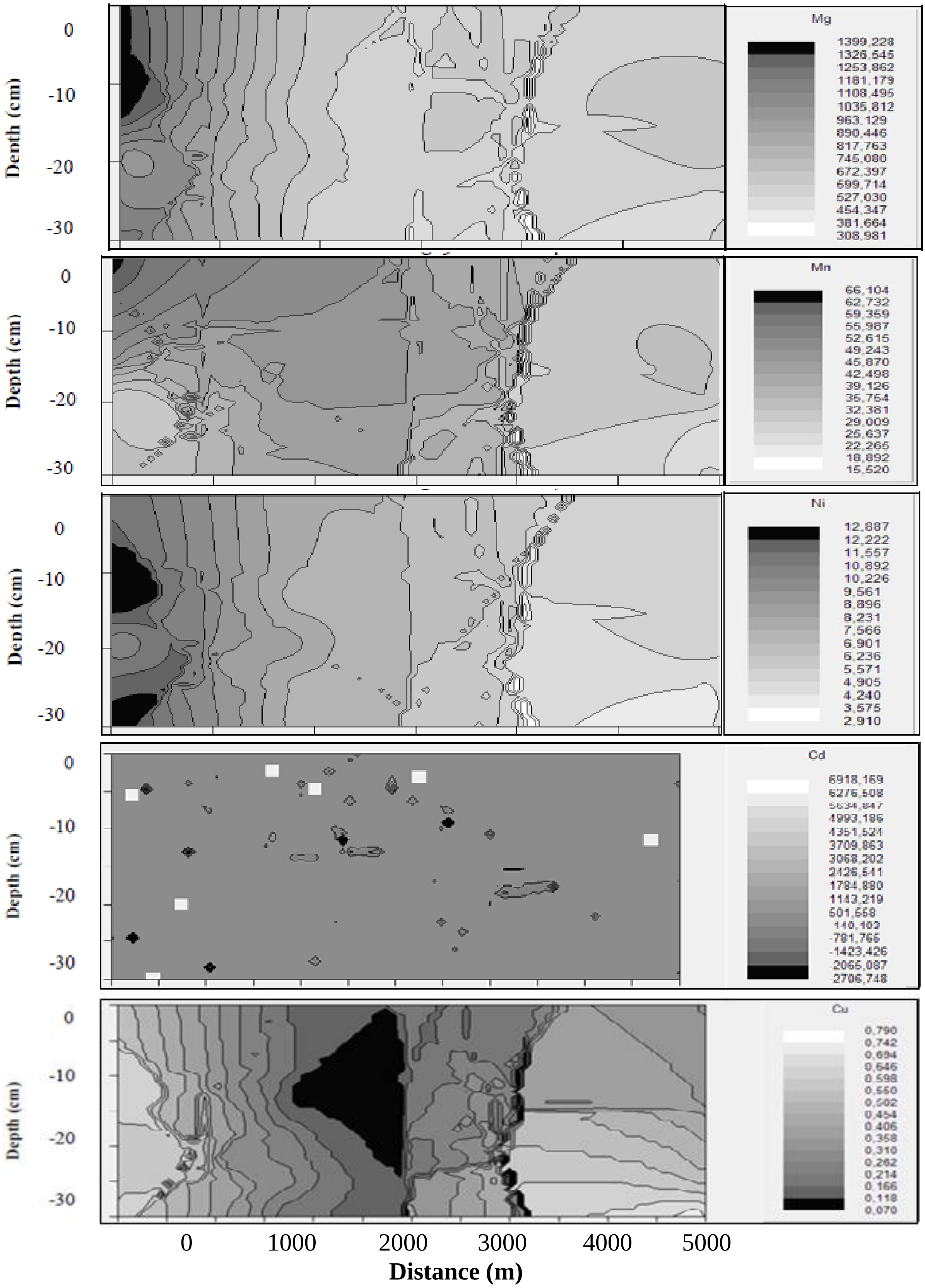

Fig. 4 (Cont.) Horizontal and vertical distribution (µg/g) of metal concentrations along the transect.

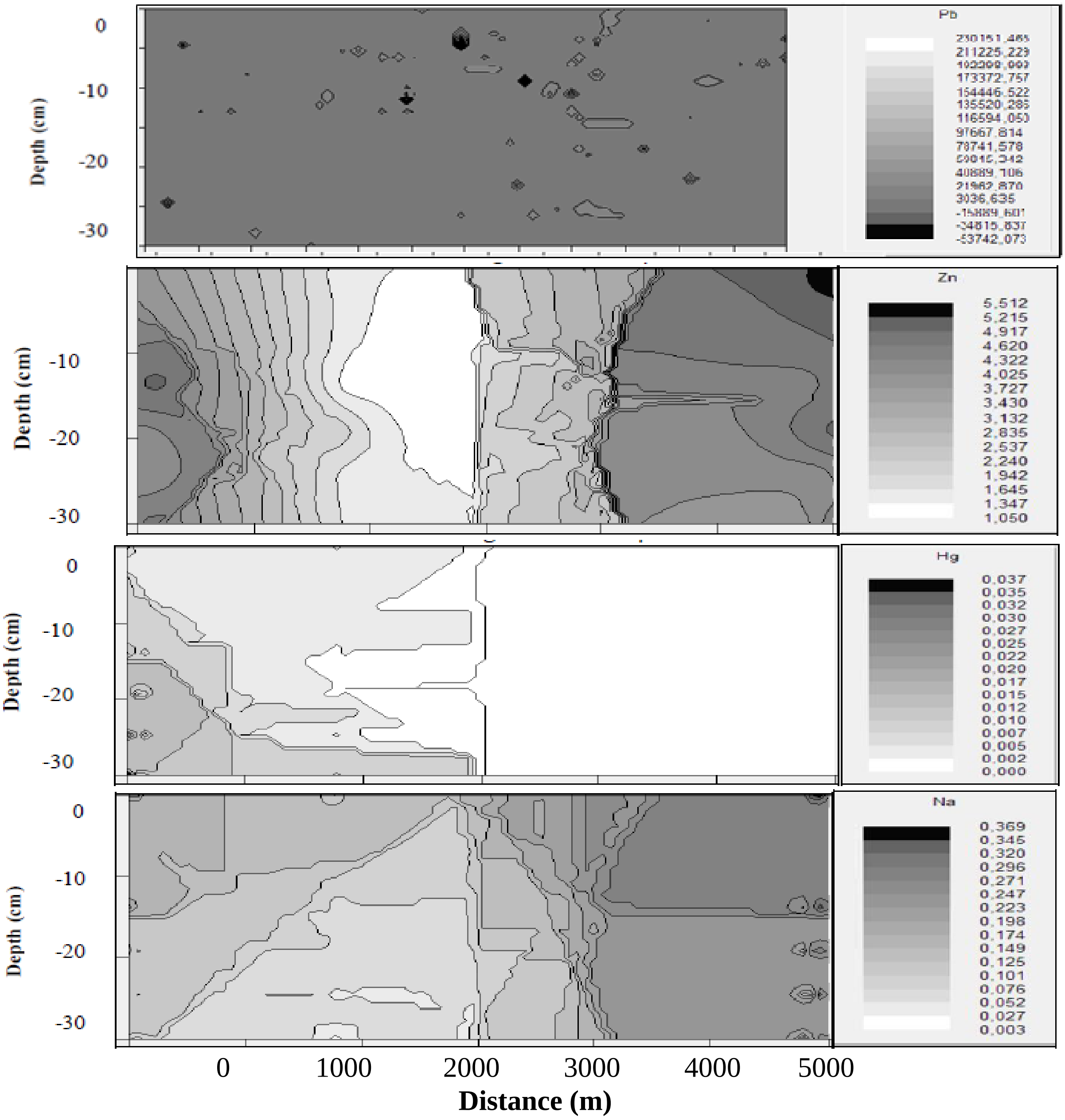

Fig. 4 (Cont.) Horizontal and vertical distribution of metal concentrations (µg/g) along the transect.

There are several clear trends in the distribution of the Fe, Mg, Ca, Co, Cr, K, Mn, and Ni, concentrations as they gradually increased from SW to NE, which can be attributed to gradual changes in composition of parent materials from North to South besides contributions from the urban activities such as industrial emissions and household wastes.

Concentrations of Cd, Pb, and Cu showed patchy distribution. Concentrations Cu exhibited hot spots nearby the center of the urban area. Greater Zn concentrations occurred at both ends of the transect compared to values closer to city center. Concentration of Hg was far greater in the NE half of the study area than SW half, while concentration of Na was far greater in the SW half of the study area than NE half. In general, horizontal variation of heavy metals were greater compared to their vertical variation. No obvious relation was detected between pH and concentration of any of studied heavy metals.

The impact of the studied heavy metals should be mitigated. Unfortunately, high soil sodicity does not allow these areas are to be vegetated. In the past, many attempts were made to vegetate these soils, and all these attempts were unsuccessful. The city sprawls Omni directionally, resulting in excavate tremendous amounts of earth each year. Excavated material should be handled very carefully and protected in safe areas to avoid hazard of the heavy metals, especially those with high concentration. In other areas, the land may be left untouched or some special plantation techniques may be used to vegetate these areas. Some sodicity tolerant grasses and bushes may be used in plantations. However, the chemical, biological, and physical properties of these soils should be considered carefully before any action to be taken for plantations. For example, some of these soils derived from serpentine and gypsum rocks and this may further obstruct adaptation of the plants to these localities. Since soils are considerably variable in parent material, plantations should be done site specifically. Low precipitation and high evapotranspiration result in parent materials dominate soil properties and relatively uniform accumulation of heavy metals by depth. Vince *et al.* (2014) specified that heavy metals can incorporate to the soil during the weathering of the soil-forming rocks. Thus, every soil may contain heavy metals more or less, depending on their concentration in the parent material.

Low Ca/Mg ratio is typical indicator of serpentine (Schaetzl and Anderson, 2005). Our low Ca/Mg (Table 3) ratio showed that the parent material of studied soils possesses serpentine in some degree. The poor productivity of serpentine soils was first attributed to the low Ca:Mg ratio present in serpentine substrates by Loew and May (1901). In general, soils derived from serpentine in arid and semi-arid regions are poor in organic matter and low in cation exchange capacity (O'Dell and Claassen, 2009).

4. Conclusions

We studied horizontal and vertical distribution of Mg, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, Hg, Pb, Na, K, and Ca/Mg along a 7-km transect in Cankırı, North central Anatolia, Turkey. Their vertical and horizontal spatial distribution showed that concentrations of these heavy metals are principally controlled by their geologic origin since their spatial pattern exhibited prominent extremes and discontinuities, consistent with the observed pattern of parent material. Surface maps showed that concentrations of Fe and Mg exceeded their critical thresholds at many localities across the transect. These soils are highly vulnerable to water and wind erosions due to their poor hydraulic conductivity. Care should be taken to protect city and nearby streams from pollution of these metals. The soils may be vegetated to decrease surface erosion, avoiding pollution of nearby stream and residential areas by eroded sediments, transported by water and wind. The city is spreading in all directions, resulting in tremendous amount of excavated earth material exposed to air, posing a high risk to contaminate nearby residential areas by windblown dusts. Therefore, the excavated material in construction areas should be handled carefully and stored in safe places to avoid environmental hazard of these heavy metals (especially Fe and Mg). The parent material of the soils comprises serpentine, which is characterized by low Ca/Mg ratio. The serpentine derived soils in arid and semi-arid regions often pose Mg contamination and have specifically adapted vegetation. Since the study soils considerably vary site-specifically depending on the dominance of parent material type (lacustrine sodic clay deposits, serpentine, gypsum, etc.), the plants should be chosen site-specifically for a successful plant adaptation in vegetating the bare soils.

Acknowledgments

The authors thank to Dr. Serhat Döker and Musa Uslu for their assistance in heavy metal analyses.

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