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A study on distribution of heavy metal pollution on the urban parks soils in Çankırı, Türkiye

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Abstract **Research Article**

Soil is a crucial component of rural and urban environments. Urban soils in Çankırı have a high potential impact on soil quality. To date, little research on soil pollution has been conducted in Çankırı's urban parks has been conducted. To identify the concentrations and sources of heavy metals in soil, and to assess the soil environmental quality, samples were collected from 10 urban parks soils and different time located in the city of Çankırı (total 90 soil samples). The concentrations of B, Cd, Cr, Fe, Mn, Cu, Ni, Pb, and Zn were analyzed in the samples using an ICP (Inductively Coupled Plasma Mass Spectrometry). The mean concentrations (mg/l) were Mn>Fe>Zn>Cu>Ni>Pb>B>Cd>Cr. Considering the heavy metal concentrations obtained in the study, all of these values were found below the acceptable However, in some parks of the study area, some elements were also slightly raised, the transported soils in urban parks should be handled carefully and to avoid an environmental hazard of these heavy metals.

Key Words: Heavy metals, Çankırı, urban soils, urban park

Çankırı'daki kent parkları topraklarında ağır metal kirliliğinin dağılımı

ÖZ

Toprak, kırsal ve kentsel çevrenin önemli bir bileşenidir. Çankırı'daki kentsel topraklar, toprak kalitesi üzerinde yüksek bir potansiyel etkiye sahiptir. Bugüne kadar, Çankırı'nın kentsel parklarında toprak kirliliği üzerine çok az araştırma yapılmıştır. Topraktaki ağır metallerin konsantrasyonlarını ve kaynaklarını belirlemek ve toprağın çevresel kalitesini değerlendirmek için, Çankırı kentinde bulunan 10 kent parkı toprağından ve farklı zamanlarda örnekler toplanmıştır (toplam 90 toprak örneği). Örneklerdeki B, Cd, Cr, Fe, Mn, Cu, Ni, Pb ve Zn konsantrasyonları analiz edilmiştir. Ağır metal konsantrasyonları ICP (İndüktif Eşleşmiş Plazma Kütle Spektrometresi) kullanılarak analiz edilmiştir. Ortalama konsantrasyonlar (mg/l) Mn>Fe>Zn>Cu>Ni>Pb>B>Cd>Cr şeklindeydi. Çalışmada elde edilen ağır metal konsantrasyonları göz önüne alındığında, bu değerlerin tümü kabul edilebilir değerlerin altında bulunmuştur. Ancak, çalışma alanındaki bazı parklarda bazı elementler de hafifçe yükselmiştir, kent parklarındaki taşınan topraklar dikkatli bir şekilde ele alınmalı ve bu ağır metallerin çevresel bir tehlikesinden kaçınılmalıdır.

Anahtar Kelimeler: Ağır metaller, Çankırı, kent toprakları, kent parkları

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1. Introduction

Urbanization studies are mostly focused on spatial planning, economic, and social problems. However, urbanization has negative effects on ecosystems. The major of problems of urbanization regarding the ecosystem is the increase of heavy metal accumulation in the urban soils. Heavy metals can be toxic even at low concentrations due to their high concentration. This is acutely evident in urban areas where various sources release large quantities of heavy metals. Heavy metals found in agricultural soils, urban soils, and especially soils in parks, gardens and residential areas can easily contaminate the human body (Mielke et al., 1999; Madrid et al., 2002). Furthermore, urban soils receive higher than normal loads of contaminants from traffic and, in heavily industrialized cities, industrial activity (Bullock and Gregory, 1991).

Since the origin and sources of heavy metals are different, many researchers have pointed out that urban soils need to be better known. For example, Ni and Cd have terrestrial origins while Pb, Fr, and Zn are of more anthropogenic origin (Bilos et al., 2001). Several researchers have indicated the need for a better understanding of urban soil pollution and a number of studies have been conducted on the distribution of heavy metals around the world (De Kimple and Morel, 2000; Manta et al., 2002, Chen et al., 2004, Wei and Yang, 2010, Erşahin et al., 2018).

Heavy metals in urban soils may come from various human activities, industrial and energy production, construction, and vehicle exhaust (Martin et al., 1998; Li et al., 2001). These activities send heavy metals air and the metals subsequently are deposited into urban soil, parks, and gardens as the metal-containing dust falls. Studies of urban soils in many cities have been carried out around the world (Beyer et al., 1996, Paterson et al., 1996, Sánchez Martín et al., 2000, (Cyrys et al., 2003, Erşahin et al., 2018). On the other hand, there are different sources of heavy metals in the environment. These sources can be both of natural or anthropogenic origin. Heavy metals occur naturally in rocks and soils (Khalilova and Mammadov, 2016). Accordingly Facchinelli et al. (2001), heavy metals occur in almost all soils naturally, but their concentrations and impact on the soil can be influenced by many factors (Erşahin et. al., 2018). Aviles et al., (2012) reported that anthropogenic sources of heavy metals in industrial discharges, vehicle emissions, metal mining, atmospheric deposition of particles, and land application of fertilizers.

Little information is available on heavy metal concentrations in soils of urban parks. Akyıldız and Karataş (2018) reported some heavy metal (Ni, As, Cr, and Al) distribution in the Adana urban soils. Researchers found that heavy metals are generally caused by environmental factors and that the geological structure. They stated that geological structure in the region may contribute in the increase of Cr and Ni elements. Chen et al., (2005) reported that Ni and Zn levels were controlled by parent material in the park soils, Cu, Pb and, in part, Zn were accounted for mainly by anthropogenic activities in Beijing, China In addition they stated that no obvious pollution by Ni was observed in the soils of the parks in Beijing. Madrid et al., (2002) reported also that heavy metal pollution exists in some soils within the urban area of Seville, particularly for Cu, Pb and Zn.

This study has been conducted on the distribution of heavy metal contents of some urban parks in Çankırı. The concentrations and pollution levels of park soil B, Cd, Cr, Fe, Mn, Cu, Ni, Pb, and Zn in urban park soils were assessed to evaluate the environmental quality of the soils in urban parks and the potential ecological risks.

2. Material and Method

2.1. Study area

The study area is located in North Central Anatolia, Turkey (Fig.1). The city is 723 m above sea level. Climate in the study area is the dry sub-humid/semi-arid Central Anatolian climate according to Iyigun et al. Long-term mean annual precipitation ranges from 406.0 to 538.0 mm, mean annual temperature from 9.1 to 11.1 ºC, and mean relative humidity from 61.0 to 66.0%. (Anonim, 2023).

Figure 1. Location map of study area

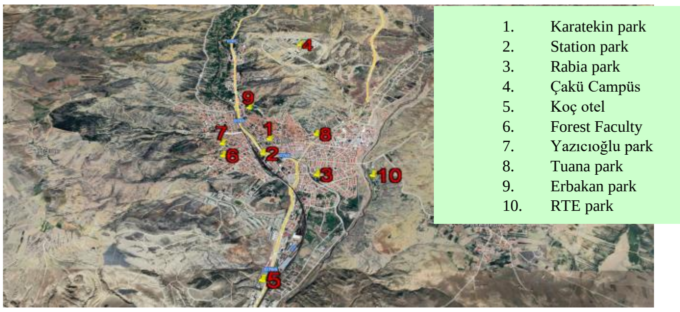

Figure 2. Soil samples point map of study area (RTE: Recep Tayyip Erdoğan)

2.2. Soil sampling and analysis

A total of 90 soil samples were collected from ten different parks and times (June, August, and October) in Çankırı city (Fig. 2). Depending on the area of the parks, 3 sub-samples of the topsoil (0–20 cm) were collected urban park soils in each park and mixed thoroughly to get a representative sample. In addition, their coordinates were recorded using global positioning system (GPS) tool. Samples were air-dried and sieved through a 2 mm sieve to be prepared for analyses. Soil physico-chemical properties, heavy metal concentration were determined based on literatures. Table 1 shows the selected analytical protocols.

The concentrations of heavy metals in soils mainly depend on the type and chemistry of the main materials in soils. The mean of some heavy metals found in soils their concentration is shown in Table 2.

Table 1. Soil variables and the methods used for their analysis

Soil property	Methods/device	Reference
Soil texture (Clay, Silt and Sand) (%)	Mechanical analysis	Gee and Bouder 1986
Field capacity (%)	Pressure chambers	Cassel and Nielsen 1986
Wilting point (%)	Pressure chambers	Cassel and Nielsen 1986
Available water capacity (%)	Difference between field capacity and wilting point	Cassel and Nielsen 1986
Electrical conductivity (dSm^{-1})	With an EC electrode in 1 / 2.5 soil-water suspension	Rhoades *et al.*1999
Soil reaction (pH)	With a pH electrode in 1 / 2.5 soil-water suspension	Rhoades *et al.* 1999
Organic matter content (%)	Walkley-Black method	Nelson and Sommers 1982
$CaCO_3$ content (%)	Scheibler calcimeter	Çağlar 1958
Aggregate stability index (%)	Wet sieving	Kemper and Rosenau 1986
Total heavy metal (B, Cd, Cr, Fe, Mn, Cu, Ni, Pb, and Zn) (mg/l)	ICP-OES detection	Kloke (1980)

Table 2. Pollution limits of the World Health Organization (Chiroma et al., 2014)

Elements	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
WHO and FAO (mg/l)	20	3	50	100	100	50000	2000	50	100	300

The mean concentration of cadmium in soils is six times the mean concentration in the stratum. In addition, concentrations of Pb, Hg, and Zn in soils are two times the average concentrations in the earth's crust (Türkoğlu, 2006). The calculation of the enrichment factors (EF) for the heavy metals was made using an equation suggested by Sposito (1989).

$$EF= (HMsoil) / (HMearth\ crust) \quad (1)$$

where HMsoil is the total heavy metal concentration in the soil sample, and HM earth is the mean heavy metal concentration in the earth's crust, which is 0.11 mg kg-1 for Cd, 25 for Cu, 126 for Cr, 24 for Co, 56 for Ni, 14 for Pb, for Mn 716, and 65 mg kg-1 for Zn (Sposito, 1989). EF values were also interpreted as suggested by Zhang and Liu (2002): if 0.5≤EF≤1.5, it indicates that the metal could be mainly from natural weathering process, and if EF>1.5, it indicates that the metal is from anthropogenic sources, or a greater percentage of the metal is from non-natural weathering process.

3. Results and Discussion

The descriptive statistical parameters such as mean, maximum, minimum, and coefficients of variation (CV) of some basic soil properties related to 90 soil samples taken from surface (0-20 cm) of the urban parks of the Çankırı province were given in Table 3. In order to determine variability of some soil properties, many researchers offer to investigate coefficient of variation (CV). According to Mallants et al., 1996, CV values were classified as low (<15%), medium (15-35%) and moderate (> 35%). In this case, variables of bulk density, aggregate stability, and pH have low CV. It has been reported in many studies that pH varies low (Erşahin, 1999; Mulla and Mc Bratney, 2000; Dikmen et al., 2017, Kavaklıgil and Erşahin, 2022). According to this result, it can be interpreted that pH is more similar across the landscape. On the other hand, the variables of soil mositure, plant available water content and EC of soil properties had a high level of variability. As for the concentrations of heavy metals in soils given in Table 3, it was determined that the variations for heavy metals were generally high. Greatest variation occurred for Zn and lowest for Cd.

Table 3. Descriptive statistical analysis of physico-chemical properties and heavy metal of soil samples

Parameter	Min	Max.	Mean	SD	Skewness	Kurtosis	CV
BD (g/cm^3)	1.18	2.01	1.49	0.17	0.39	-0.12	11.40
Sand (%)	14.10	64.10	41.70	11.40	-0.36	-0.45	27.3
Clay (%)	17.00	63.40	38.32	9.67	0.60	0.03	25.31
Silt (%)	10.00	31.40	19.95	4.86	-0.17	-0.32	23.05
AS (%)	0.37	0.57	0,49	0.03	-0.78	1.82	6.12
$CaCO_3$ (%)	5.20	20.78	10.77	3.56	0.91	0.23	33.05
SOM (%)	0.68	3.07	1.97	0.59	-0.21	-0.81	29.94
FC (%)	10.67	67.91	33.54	14.75	0.87	-0.23	43.97
WP (%)	5.39	36.57	15.84	5.61	0.61	1.14	35.41
AWT (%)	1.01	51.12	17.70	13.52	0.92	-0.30	76.38
pH (%)	7.22	8.13	7.79	0.13	-0.66	2.61	1.66
EC (µS/cm)	126.9	2080.0	532.13	432.7	1.99	3.62	81.31
Heavy Metals							
B (mg/l)	0.01	0.78	0.12	0.09	3.63	22.5	75.0
Cd (mg/l)	0.02	0.04	0.03	0.01	2.92	11.51	0.33
Cr (mg/l)	0,01	0.05	0.03	0.01	1.54	2.08	33.33
Cu (mg/l)	0.10	2.29	0.63	0.35	1.83	5.65	55.55
Fe (mg/l)	0.06	8.92	2.25	1.58	1.98	4.34	70.21
Mn (mg/l)	0.45	7.82	3.39	1.75	0.50	-0.18	51.62
Ni (mg/l)	0.02	1.61	0.48	0.33	1.25	1.50	68.75
Pb (mg/l)	0,01	1.24	0.28	0.27	1.59	2.15	96.42
Zn (mg/l)	0.01	5.20	0.86	1.09	2.68	7.23	126.74

SD: standard deviation, CV: coefficient variation, BD: bulk density, AS: aggregate stability, SOM: soil organic matter, FC: field capacity, WP: wilting point, AWT: available water content.

The soils are clay sand with a pH<8.0 and have very low aggregate stability (Table 3). The general Fe rate is 5% on average according to WHO and FAO data (Table 2). Results with these standards compared, it shows that there is no iron-related pollution in the urban park soils. The mean value of Mn content was found to 3.39. The value of Mn in the soil is below 2000 mg/kg, (2 mg/l) which is the value indicated by WHO and FAO. As a result, Mn values are within the range (Table 3). According to the analysis of soil samples, the heavy metal content concentration did not exceed their permissible threshold level in all the soil samples.

In addition to obtain real heavy metals' values, all the elements were additionally grouped by Zhang and Liu (2002). Some EF values for the soils are given in Table 4. The EF values 0.5≤EF≤1.5 for Cd, Cu, Cr, Ni, Pb, Mn and Zn pointed to the absence of the soil's enrichment with these elements.
(Table 4).

Table 4 Some enrichment factors (EF) for the soils, mg kg^{-1}

Heavy Metals	Cd	Cu	Cr	Ni	Pb	Mn	Zn
	0.27	0.02	0.0002	0.008	0.02	0.004	0.013

4. Conclusion

This present study was conducted for the distribution of heavy metal contents and their enrichment factors in urban parks soils in Çankırı. For this purpose, 90 soil samples were collected form surface soil in parks. According to the results of the analysis, whether the elements in the park soils create pollution and the accumulation of elements and information was obtained. The results showed that mostly the concentration did not exceded their threshold levels. Besides, all heavy metal elements did not exceed the minimal enrichment level. However, in some regions of the study area, the Mn and Fe contents were also slightly raised, this result possibly stems from anthropogenic effects. Considerably vary site-specifically depending on the dominance of the anthropogenic effects the plants should be chosen site-specifically. Also, this is a study conducted by a specific research group. Future or other studies may have different conclusions from these authors, so it has the potential to form the basis for future studies.

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