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Evaluation of Heavy Metal Accumulation and Biomonitoring Properties in Some Brassicaceae Species in Amasya Province of Turkey

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ABSTRACT

In this study, heavy metals (Cr, Pb, Zn, Cu, and Cd) contents of five Brassicaceae species grown in four different locations in Turkey were determined, mapped, and interpreted. Spatial analyses of the collected data were conducted in GIS, and thematic maps for average heavy metal accumulations including root, stem, and leaf of each species was developed. The biomonitoring potentials of species was assessed based on the statistical analyses results of the different localities. The heavy metal deposition characteristics of the plants showed differences. The most accumulated heavy metal was Zn, while Cd was the least accumulated. *Capsella bursa-pastoris* had the highest Cr and Cu accumulation compared to other species. *Lepidium draba,* on the other hand, accumulated Pb and Zn at most. *Sisymbrium loeselii* had the highest Cd accumulation compared to the other species. The results of the present study have indicated that *Lepidium draba* (Zn and Pb), *Capsella bursa-pastoris* (Cr and Cu) and *Sisymbrium loeselii* (Cd) can be safely used for biomonitoring studies.

Keywords: Phytoremediation, Geographic Information Systems, Spatial Analysis, Traffic Density

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INTRODUCTION

Heavy metals are found as oxide, sulfur, and carbonate compounds or bonded to silicate minerals. They are very hazardous for the environment and incorporate into food chains (Armitage *et al*., 2007; Sakan *et al*., 2009). Contamination with heavy metals usually results from industrial activities, such as mining and smelting of metalliferous ores, electroplating, gas exhaust, energy and fuel production, fertilizer and pesticide application, and generation of municipal waste, which causes release of considerable amount of heavy metals to the atmosphere and soil (Karimi *et al*., 2017; Ayoubi *et al*., 2018a, 2018b, 2019; Souri *et al*., 2018; Hatamian *et al*., 2020) The primary sources of heavy metals are volcanic activity, weathering of minerals, erosion, mining, smelting, pesticide and fertilizer, sludge dumping, industrial discharge, atmospheric deposition, etc (Ataabadi *et al*., 2010; Özay and Mammadov, 2013).

The essential mechanisms of heavy metal emissions from vehicles include fuel and engine oil consumption, tire wear, brake wear, and road abrasion. Cd pollution mainly originates from engine oil consumption. Tire wear is an essential source for Zn pollution (Al-Khashman *et al*.,

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2011; Karakoyun and Osma, 2015). Similarly, brake wear causes Cu and Pb pollution. The use of unleaded gasoline has been increased in recent years, and this caused a subsequent reduction in automobile emissions of Pb. However, it may still occur in the exhaust gas and come from worn metal alloys in the engine (Taghipour *et al.*, 2011; Zhang *et al.,* 2012; Bilge and Çimrin, 2013).

Accumulation of heavy metals in higher plants depends on the binding and solubility of the particles deposited on leaf surfaces and plant species characteristics, concentrations, and bioavailability of elements in the soil (Olowoyo *et al.,* 2010; Hatamian *et al.,* 2019). Biomonitoring is generally defined as "the systematic use of living plant parts or their responses to determine the condition or changes of the environment" (Gerhardt, 2000). Biomonitoring determines the use of responses of individual plants or plant associations at several levels to detect or predict the environment's health. When some plant species are sensitive to single pollutants or mixtures of contaminants, these species are used to monitor air pollutants' effects as bioindicator plants. Highway surfaces have served as temporary sinks for various types of heavy metals, and these heavy metals are washed off during rainfall to the surrounding environment (Pal, 2014).

A bioconcentration factor (BCF) indicates heavy metal uptake, provides an index of the plant's ability to accumulate a particular metal in relation to its concentration in the organic substrate. Heavy metals with a BCF value greater than 1 can be defined as the most assimilated. (Radulescu *et al.,* 2013). Olowoyo *et al.* (2010) and Zhang *et al.* (2017) reported that if BCF value is greater than 1, the plant species is bioaccumulator of a particular heavy metal. However, BCF values smaller than 1 indicate that a plant species absorbs a heavy metal in limited concentration, which means a low amount of translocation from the soil to plant leaves.

This study was carried out in the Amasya Province of Turkey, one of the most important cities in the central Black Sea Region of Turkey, where mining facilities were prevalent in the past years, but it was ended after the earthquake in 1996. Amasya is also highly industrialized, and there are several coal and sugar factories. Additionally, the textile industry has been developed in recent years (Agency, 2017). Among the main air pollution factors in Amasya City Center are fuels used in heating, exhaust gas emissions from motor vehicles, and emissions from the industry (Highways, 2015). The present study aimed to determine heavy metal accumulation in some Brassicaceae members in Amasya City and suburban areas to find a potential candidate for phytoremediation.

MATERIALS AND METHODS

The study area's climate shows 'Semi-arid Upper Mediterranean Bioclimate' characteristics with cold winters (Akman, 1999). The topographic layout of the area shows mountainous characters and elevation changes between 148 and 2080 m. The study area is located between 35°38'18"- 36°0 7'21" N and 40°32'25"- 40°48'42" E within the boundaries of the province (Figure 1). The study area's length is 42 km east-west and 29 km in a north-south direction. The geology of the region has a wide range of rock assemblages, from durable metamorphic rocks belonging to the Paleozoic Era to the existing weak units formed in basins and stream beds. The boundaries between these rock assemblages are mostly under the control of structural lines due to ancient tectonism, and existing sediments are interrupted by active faults (Anonym, 2018).

This study was conducted in 4 locations including (1) near the highway, (2) city center, (3) suburban areas, and (4) control (Figure 1). Five sampling points were chosen for each location. Selected locations had different traffic densities. The impact of traffic density on heavy metal contents was observed in June 2015. The control group

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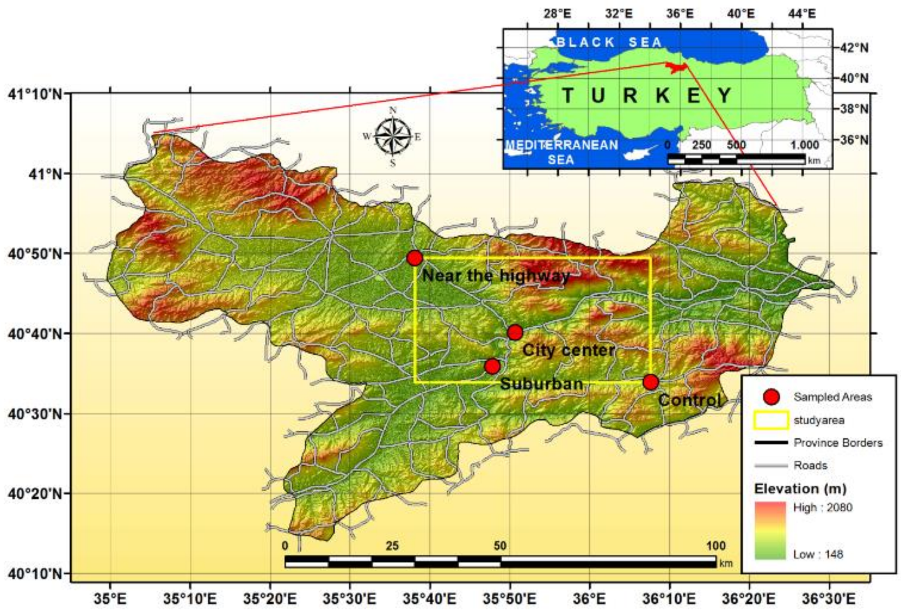

Figure 1. Geographic location of study area and topographic features.

was rural areas without traffic density and settlements. Mean daily traffic density was reported in the 16201 number of vehicles/hour in Amasya City Center and 11291 vehicles/hour in Amasya-Suluova highway for 2015 by the Turkish Ministry of Transport Maritime Affairs and Communication General Directory of Highways (Highways, 2015). Sampling localities and mean traffic density values are given in Table 1.

Five Brassicaceae species were selected for the study including *Calepina irregularis* L., *Capsella bursa-pastoris* (L.) Medik., *Lepidium draba* L., *Sisymbrium loeselii* L., and *Sisymbrium altissimum* L. The root, stem, and leaf samples of the species were used. Plant samples were collected by sterile plastic gloves to prevent contamination in the sampling locations, and survey was performed in June 2015.

In the laboratory, plant samples were grouped as root, stem, and leaf. All plant materials were dried to a constant weight at 70 °C using a microwave oven, then, 0.5 g of the dried leaf samples were powdered and extracted with 10 mL aqua regia, which was made by mixing hydrochloric acid (HCl) and nitric acid (HNO_3) in a ratio of 3:1. The digest was filtered through a Whatman filter paper No 42. The amounts of heavy metal accumulated in soil and plant organs were determined by three replicates (ICP-OES), and the obtained data were evaluated.

After obtaining the laboratory analysis results, average amounts of each heavy metal were calculated based on their total accumulations including root, stem, and leaf in each plant species. Employing geographic references, a point (XYZ) database was established as a Microsoft Excel file to create interpolated surface maps. Then, spatial analyses of the XYZ data were conducted in GIS, and a series of thematic maps were developed. Throughout the mapping process, ArcGIS software was utilized, and Inverse Distance Weighted (IDW) interpolation method was adopted (McCoy, 2004). As a result, 25 average heavy metal maps were produced for five plant species and five heavy metals (Cd, Cr, Cu, Pb, Zn). Finally, these thematic maps were evaluated, and their geographic distributions were interpreted.

General Linear Models ANOVA, MANOVA, and Tukey's Honestly

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Table 1. Sampling points and traffic densities.

Locality		Locality	Coordinates	The number of Automobiles, medium-loaded commercial vehicle, bus, truck and trailers per hour
1	Roadside	AmasyaSuluova highway	N 40°42.58' - E 35°48.17'	
2	Roadside	AmasyaSuluova highway	N 40°44.07' - E 35°46.18'	
3	Roadside	AmasyaSuluova highway	N 40°48.38' - E 35°39.49'	(8515+441+310+ 887+1138= 11291)
4	Roadside	AmasyaSuluova highway	N 40°49.43' - E 35°38.09'	
5	Roadside	AmasyaSuluova highway	N 40°50.49' - E 35°37.84'	
6	City Center	Amasya	N 40°40.10' - E 35°50.54'	
7	City Center	Amasya	N 40°40.14' - E 35°50.23'	
8	City Center	Amasya	N 40°39.86' – E 35°50.48'	(12203+1461+ 161+1763+613= 16201
9	City Center	Amasya	N 40°37.88' – E 35°48.91'	
10	City Center	Amasya	N 40°33.80' - E 35°47.44'	
11	Suburban	Amasyaİpekköy	N 40°36.30' - E 35°48.74'	
12	Suburban	Amasyaİpekköy	N 40°36'6.4" - E 35°48'44.7"	
13	Suburban	Amasya Forest ties	N 40°36'38" - E 35°47'6.4"	3-5 vehicles per minute
14	Suburban	AmasyaHelvacı	N 40°37'12" - E 35°49'16.7"	
15	Suburban	AmasyaKoza Neighborhood	N 40°36'11" - E 35°49'2.8"	
16	Control	AmasyaAydınca	N 40°33.92' - E 036°7.587'	
17	Control	AmasyaYenice	N 40°41.84' - E 35°57.266'	
18	Control	AmasyaYenice	N40°68.94' - E 35°51.549'	No traffic
19	Control	AmasyaZiyaret	N 40°40.84' - E 35°52.312'	
20	Control	AmasyaZiyaret	N 40°41'52" - E 35°51'27"	

Significant Difference (HSD) tests were carried out by using SPSS 22.0 version. Data were tested for normality using the Kolmogorov-Smirnov test (Corp, 2013) before conducting ANOVA and MANOVA.

BCF values of plant species were calculated according to the following formula (Ling *et al.*, 2017).

$$\mathrm{BCF} = \frac{\text{metal concentration in shoot}}{\text{metal concentration in substrate}} \quad (1)$$

Many researchers have used the geoaccumulation index to determine anthropogenic pollution in soils and sediments. (Loska *et al.*, 2003; Lokeshwari and Chandrappa, 2006). Geoaccumulation index values were computed using the following formula (Müller, 1979).

$$Igeo = \log_2[\frac{\mathrm{Cn}}{1.5\mathrm{Bn}}] \quad (2)$$

Where, Cn is the measured concentration of the element in the environment and Bn is the geochemical background value in soil. The constant 1.5 allows us to analyze natural fluctuations in the content of a given substance in the environment and to detect minimal anthropogenic influences (Elbagermi and Edwards, 2013).

RESULTS

Spatial distribution of heavy metal based on their total accumulations, including root, stem, and leaf in each plant species is shown in Figure 2. Produced raster maps showed similarities and differences in terms of plant species and heavy metal properties. For instance, *L. draba* heavy metal accumulation characteristics have been perceived similar for Cr, Cu, Zn, and Pb. However, *L. draba* showed different heavy metal accumulation characteristics for Cd. Likewise, the heavy metal deposition properties of the *S. loeselii* were similar for all heavy metals, except Cd. In the other raster maps, high heavy metal

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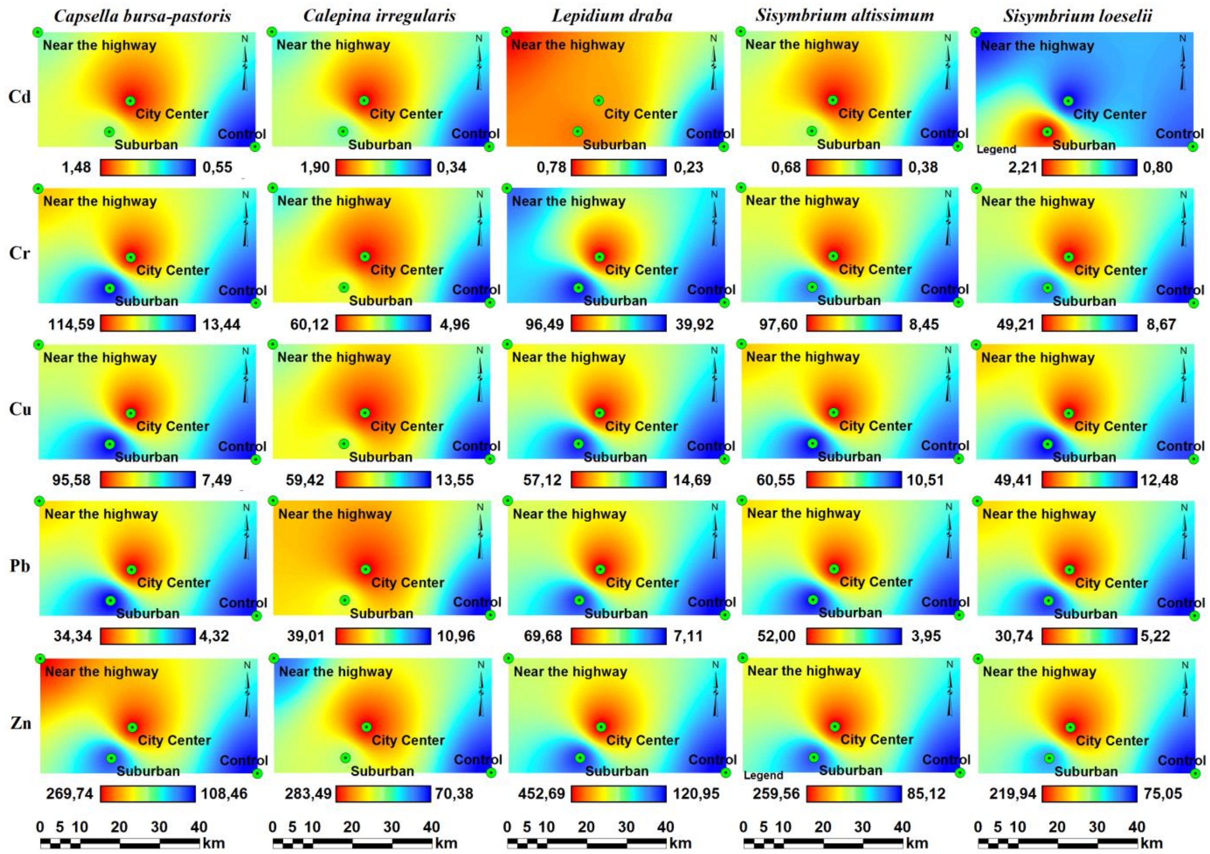

Figure 2. Spatial distribution of heavy metals concentrations in different plant parts.

amounts were observed in City Center and near the highway locations, and low heavy metal amounts in the control and suburban areas. Consequently, all these maps showed almost the same characteristics.

On the other hand, the plants' heavy metal deposition characteristics also showed differences from each other. For example, in all plants, the most accumulated heavy metal was Zn, while Cd was least accumulated. However, their concentrations varied according to the species. *C. bursa-pastoris* had the highest Cr (114.59 ppm) and Cu (95.58 ppm) accumulation compared to other species. *L. draba*, on the other hand, accumulated Pb (69.68 ppm) and Zn (452.69 ppm) at most. *S. loeselii* had the highest Cd (2.21 ppm) accumulation compared to other species.

According to the MANOVA results, heavy metal contents varied significantly ($p<0.01$) among plant species, plant parts, and localities. All of the interactions among these parameters were also found to be significant (Table 2). The highest heavy metal concentrations were found in the City Centre, where the highest traffic density occurred. The highest heavy metal concentrations were found in leaves, and Zn concentrations were the highest in all plant parts (Table 3). The highest Cd concentrations were found in *S. loeselii*. The highest Cr and Cu concentrations were found in *C. bursa-pastoris*, while the highest Zn and Pb concentrations were in *L. draba* (Table 4). The highest heavy metal concentrations were found in City Centre samples, while the lowest heavy metal concentrations were found in the control and suburban samples (Table 5).

According to the geoaccumulation index (*I*geo) values, all localities were moderately

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Table 2. MANOVA results of heavy metals concentrations in species, plant parts, and localities (******p<0.01,***** p<0.05).

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Species	Cd	60.596	4	15.149	50.972	0.00**
	Cr	137511.947	4	34377.987	22.537	0.00**
	Cu	17942,809	4	4485.702	11.723	0.00**
	Zn	1523099.469	4	380774.87	56.546	0.00**
	Pb	31674.729	4	7918.682	23.705	0.00**
Plant part	Cd	57.893	2	28.947	97.396	0.00**
	Cr	268392.056	2	134196.03	87.975	0.00**
	Cu	87884.299	2	43942.15	114.843	0.00**
	Zn	1593001.524	2	796500.76	118.282	0.00**
	Pb	16514.698	2	8257.349	24.719	0.00**
Locality	Cd	54.125	3	18.042	60.704	0.00**
	Cr	607808.621	3	202602.87	132.82	0.00**
	Cu	363090.561	3	121030.19	316.314	0.00**
	Zn	5144752.755	3	1714917.6	254.669	0.00**
	Pb	211191.269	3	70397.09	210.737	0.00**
Species * Plant part	Cd	62.038	8	7.755	26.092	0.00**
	Cr	135317.31	8	16914.664	11.089	0.00**
	Cu	65854.255	8	8231.782	21.514	0.00**
	Zn	1771851.227	8	221481.4	32,89	0,00**
	Pb	10211.673	8	1276,459	3.821	0.00**
Species * locality	Cd	91.084	12	7.59	25.539	0.00**
	Cr	155835.085	12	12986.257	8.513	0.00**
	Cu	83167.424	12	6930.619	18.113	0.00**
	Zn	1456280.689	12	121356.72	18.022	0.00**
	Pb	40793.872	12	3399.489	10.177	0.00**
Plant part * Locality	Cd	20.681	6	3.447	11.598	0.00**
	Cr	47795.51	6	7965.918	5.222	0.00**
	Cu	45652395	6	7608.732	19.886	0.00**
	Zn	961007.079	6	160167.85	23.785	0.00**
	Pb	9570.026	6	1595.004	4.775	0.00**
Species * Plant Part * Locality	Cd	69.917	24	2.913	9,802	0.00**
	Cr	213301.887	24	8887.579	5.826	0.00**
	Cu	79701.428	24	3320.893	8.679	0.00**
	Zn	911184.023	24	37966.001	5.638	0.00**
	Pb	26380.719	24	1099197	3.29	0.00**

Table 3. Mean heavy metal concentrations (mg/kg) of plant parts by Tukey's HSD test (Means followed by the same letter are not significantly different at the 0.05 level).

Plant Parts	N	Cd	Cr	Cu	Zn	Pb
Stem	302	0.672b	22.336c	21.710c	131.271c	20.581b
Root	289	0.712b	48.100b	39.704b	176.870b	21.867b
Leaf	294	1.226a	65.144a	45.711a	242.548a	29.758a

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Table 4. Mean heavy metal concentrations (mg/kg) of studied species by Tukey's HSD test (Means followed by the same letter are not significantly different at the 0.05 level).

Species	N	Cd	Cr	Cu	Zn	Pb
S.altissimum	192	0.533c	48.692b	34.006bc	161.688cd	25.151b
L. draba	180	0.597c	56.226ab	32.473bc	253.681a	32.640a
C. bursa-pastoris	165	1.013b	61.458a	45.814a	198.727b	18.515c
C. irregularis	168	1.055ab	32.813c	37.341b	163.040c	27.202b
S. loeselii	180	1.196a	25.979c	29.240c	138.069d	16.416c

Table 5. Mean heavy metal concentrations (mg/kg) of the studied localities by Tukey's HSD test (Means followed by the same letter are not significantly different at the 0.05 level).

Locality	N	Cd	Cr	Cu	Zn	Pb
Near the highway	225	0.784b	52.850b	44.965b	207.846b	32.486b
City center	225	1.105a	83.606a	64.417a	297.090a	45.155a
Suburban	213	1.105a	26.732c	17.994c	130.314c	11.023c
Control	222	0.490c	15.327d	13.631c	91.768d	6.607c

contaminated by Cd, Cr, Cu, and Pb. City Centre and suburban areas were moderately contaminated by Zn, while the near-highway location was heavily contaminated by Zn (Table 6.)

BCF >1 indicated that Cd was the mostly accumulated heavy metal by *C. irregularis* in the city centre (Figure 3). Similarly, Cr and Cu were the mostly absorbed heavy metals by *C. bursa-pastoris* in the City Centre. Zn was detected as the most accumulated heavy metal by *L. draba* in the City Centre.

The studied Brassicaceae species were found as bioaccumulators for Cr, Cu and Zn. However, heavy metal concentrations in *C. bursa-pastoris*, *L. draba*, *S. loeselii*, and *S. altissimum* collected from suburban sites were <1. The lowest BCF values were found for Pb (Figure 3).

DISCUSSION

Cu, Zn, and Cr concentrations were usually high and at toxic levels, in the present study. Toxic levels of Cu causes reduction in lateral root formation, formation of dark spots, growth suppression in the roots and thickening in the root cuticle (Kartal *et al.*, 2004; Yaşar, 2009). In Zn toxicity, root and shoot growth of plants decreases, roots become thinner, chlorophyll synthesis decreases, and chlorosis is observed in leaves (Rout and Das, 2009). Cr toxicity causes plant root injuries, degradation in photosynthetic pigments, oxidative stress in plants, and damage to biological membranes (Pak, 2011; Kılıç and Ipek, 2019).

Cd concentrations were below toxic levels, while Pb concentrations were at the limit of toxic levels. Cd's normal boundaries in plants are between 0.2 and 0.8 mg/kg. Cu contents in organs range from 4 to 15 ppm, and above 20 ppm are considered as toxic (Souri *et al.*, 2018, 2019). Pb concentrations range from 0.1 to 10 ppm, while above 30 ppm is considered as toxic. The average Zn concentrations range from 20 to 100 ppm, and above these values, Zn concentrations are considered toxic levels. Cr's toxic levels range from 1 to 10 ppm (Kabata-Pendias and Pendias, 2001; Ozturk *et al.*, 2017).

Table 6. Geoaccumulation index of the studied localities.

Locality	Cd	Cr	Cu	Zn	Pb
I*geo*/ City Center	0.331	0.668	0.438	0.808	0.672
I*geo*/ Near the highway	0.517	0.289	0.690	1.540	0.922
I*geo*/ Suburban	0.370	0.048	0.512	0.410	0.070

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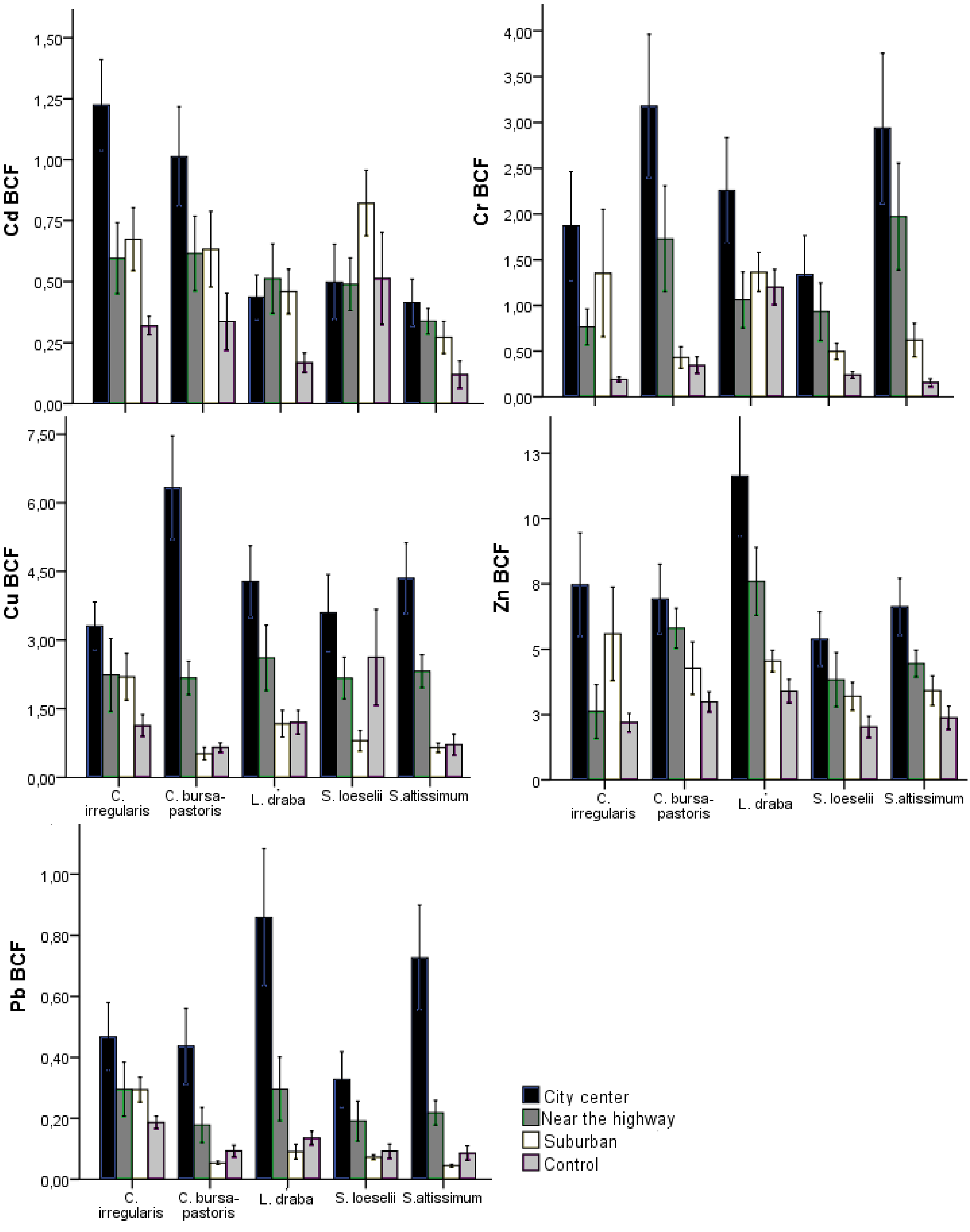

Figure 3. Bioconcentration factor (BCF) in studied plant species in City Center, suburban, near the highway, and control samples.

The mean heavy metal concentrations in plant tissues decreased as roadside>urban>suburban>rural site. The highest heavy metal concentrations were found in City Centre samples. In contrast, the lowest heavy metal concentrations were found in the control and suburban samples, except for Cd concentrations in *S. loeselii* and *L. draba*. This indicates that plants' heavy metal concentrations may change depending on the distance from the road and traffic density (Hamurcu *et al.*, 2010). Turkyilmaz *et al.* (2018) reported that dust condensation and particles occur ten times more in urban than rural areas, and eventually, atmospheric deposition is denser in urban areas. In *S. loeselii* and *L. draba* the highest Cd concentrations were found in suburban samples. Cd mostly comes from agricultural (fertilizer application) and domestic (sewage sludge) activities (Maas *et al.*, 2010; Hatamian *et al.*, 2020). Zhang *et al.* (2012) stated that the complex local terrain and environments, such as rain runoff and drainage, and wind direction and speed, might change the heavy metal contaminants distribution patterns. Zn concentrations were highest among the studied heavy metals. Pb concentrations were seven times higher in the City Centre than (control) rural areas, although the use of leaded petrol was forbade in Turkey in 2004 (Osma *et al.*, 2014). Pb concentrations around roadside declined with distance from the main roads. It has been hypothesized that Pb concentrations vary from time to time depending on the traffic density and even the season (Elbagermi and Edwards, 2013; Hatamian *et al.*, 2020).

The highest heavy metal concentrations were found in leaves, while the lowest heavy metal concentrations were found in stems. The foliar concentration of heavy metals increases directly with heavy metal concentrations in the environment (Aksoy *et al.*, 1999). Leaves exhibited the highest heavy metal concentrations compared to the roots and stems (Olowu *et al.*, 2015). It has been reported that heavy metals in the root zone were transported weakly to the stem, but more strongly mobilized to leaves when available in the stems (Sulaiman and Hamzah, 2018).

BCF refers to the most critical plant feature in phytoremediation: the uptake of metals, their mobilization into plant tissues, and storage in the aerial plant biomass (Ndeda and Manohar, 2014; Fattahi *et al.*, 2019). Olowoyo *et al.* (2010) and Zhang *et al.* (2017) stated that if BCF>1 the plant species are bioaccumulator of a particular heavy metal. BCF<1 indicates that the plant species accumulate a limited amount of heavy metal and a low amount of heavy metal is transported from the soil to the plant leaves. (Olowoyo *et al.*, 2010). BCF values of Cd for *C. irregularis* and *C. bursa-pastoris* are greater than 1 except for city centre. For other species, the BCF values of Cd are less than 1. Similarly Cr<1 in *C. irregularis* and *C. bursa-pastoris*, except for City Centre. In all of the studied plant species, the lowest BCF values were found for Pb, while the highest BCF was found for Zn and Cu. This follows several studies (Günthardt-Goerg and Vollenweider, 2007; Xu *et al.*, 2015; Zhang *et al.*, 2017). Günthardt-Goerg and Vollenweider (2007) emphasized that Pb has relatively low mobility in plant tissues and low-mobility heavy metals such as Pb directly injure the roots. The phytotoxicity of heavy metals is caused by their interaction with proteins, displacement of essential ions from binding sites and stimulation of reactive oxygen species generation. Cu and Zn are micronutrients and essential for plant growth, and only under specific conditions and high-bioavailable concentrations in plant cells they can exert a toxicity effect (Souri and Hatamian, 2019). However, Pb is classified as a non-essential micronutrient, and root uptake of Pb was somewhat limited as to their diminished transfer capacities from roots to the other plant parts (Xu *et al.*, 2015).

Geoaccumulation index (Igeo) for heavy metals were classified as uncontaminated ($I\text{geo}\leq 0$); uncontaminated to moderately contaminated ($0<I\text{geo}\leq 1$); moderately

contaminated (1<*I*geo≤2); moderately to heavily contaminated (2<*I*geo≤ 3); heavily contaminated (3<*I*geo≤4); heavily to extremely contaminated (4<*I*geo≤5); and extremely contaminated (*I*geo≥5). The ranges of *I*geo values for heavy metals in all areas ranged from (0.048) to (1.540). According to these threshold values, soils near the highways were moderately contamination for Zn. Shi *et al.* (2010) found that, in a metropolitan region of China, the geoaccumulation index of Zn was 2.44 (moderately to heavily contamination). In another study investigating traffic and dust related pollution, the soil was found to be contaminated according to Pb and Zn Igeo indexes (Ji *et al.*, 2008; Charzyński *et al.*, 2017). In this study, Igeo of Zn and Pb for the suburban area shows similar results with previous studies (Izah *et al.*, 2017; Łyszczarz *et al.*, 2020). As a result, roadside samples were mostly polluted, and all localities were moderately contaminated (Elbagermi and Edwards, 2013). The road sides are at ecological risk in terms of Zn (1.540) pollution.

Capsella bursa-pastoris (L.) Medik. was found to have the highest Cr (114.59 ppm) and Cu (95.58 ppm) accumulation compared to other species. *Lepidium draba* L., on the other hand, accumulated Pb (69.68 ppm) and Zn (452.69 ppm) at most. *Sisymbrium loeselii* L. had the highest Cd (2.21 ppm) accumulation compared to other species. The present study results indicated that *L. draba*, *C. bursa-pastoris* and *S. looselii* can be safely used for biomonitoring studies. These species' high heavy metal contents could also make them a potential candidate for phytoremediation purposes (Osma *et al.*, 2014; Karimi and Souri, 2015).

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ارزیابی انباشت فلزات سنگین و خواص پایش‌زیستی در بعضی گونه‌های تیره شب‌بو در استان آماسیا در ترکیه

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چکیده

در این پژوهش، محتوای فلزات سنگین (Cr, Pb, Cu, وCd) در پنج گونه از شب‌بویان که در چهار ناحیه مختلف ترکیه یافت می شود تعیین شد و سپس نقشه نگاری و تفسیر گردید. تحلیل پراکنش داده های جمع‌آوری شده در محیط جی.آی.اس انجام شد و نقشه های موضوعی برای میانگین انباشت فلزات سنگین در ریشه، ساقه و برگ هر یک از گونه‌ها تهیه شد. پتانسیل پایش‌زیستی گونه ها بر مبنای نتایج تحلیل آماری نواحی مختلف ارزیابی شد. ویژگی های رسوب فلزات سنگین این گونه‌ها اختلافاتی را نشان داد. در میان فلزات سنگین، Zn بیشترین انباشت را نشان داد در حالیکه انباشت Cd از همه کمتر بود. در مقایسه با گونه های دیگر، *Capsella bursa-pastoris* بیشترین انباشت *Cr*و *Cu* را داشت. از سوی دیگر، *Lepidium draba* بیشترین انباشت *Pb* و*Zn* را نشان داد. نیز، *Sisymbrium loeselii* بیشترین انباشت *Cd* را در مقایسه با دیگر فلزات نشان داد. نتایج پژوهش حاضر حکایت از آن دارد که گونه *Lepidium draba*را در مورد (*Pb* و*Zn*) ، گونه *Capsella bursa-pastoris* در مورد (*Cr*و *Cu*) و گونه *Sisymbrium loeselii* را در مورد (*Cd*) می توان با اطمینان برای مطالعات پایش‌زیستی به کار برد.

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