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Atmospheric Cd, Cr, and Zn Deposition in Several Landscape Plants in Mersin, Türkiye

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Abstract The principal problem in dense cities is air pollution and the damage to the environment caused by air pollution. Roadside landscape plants are exposed to air pollutants, especially in small urban centers caused by congested traffic, heating, and industrial enterprises. According to the type of landscape plants, being a good biomonitor varies according to their absorbing capacity of air pollutants. Chromium (Cr), cadmium (Cd), and zinc (Zn) are the leading pollutants originating from emissions. They are selected and negatively affect several landscape plants in high concentrations. This study aimed to determine their concentration changes according to organ and washing status by commonly used 14 landscape species in parks. The heavy metal holding capacity of 14 species used was compared; chromium, cadmium, and zinc concentrations changed significantly depending on the factors evaluated to adsorb them. The ranking of the accumulation levels was determined as Zn > Cr > Cd and was detected at higher levels in unwashed organs than in the others. *Chamaecyparis lawsoniana* (A. Murr.) Parl. was shown better biomonitoring features on heavy metal accumulation among all species. Its unwashed leaves' deposited Cd, Cr, and Zn were 154 ppb, 6400 ppb, and 39,940 ppb, respectively.

Keywords Atmospheric deposition · Biomonitor · Environmental pollution · Heavy metals · Plants

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1 Introduction

The density in unplanned playgrounds, parks, walking paths, residences, workplaces, and vehicle roads in cities affects air quality negatively (Zhang & Gong, 2018; Kalaycı Önaç and Gönüllü Sütçüoğlu, 2021; Yilmaz and Isinkaralar 2021a, b). Heavy metals accumulate in the organs of landscape plants in these areas, which are exposed to large amounts of emissions, revealing the general condition of the region. However, it does not affect the urban air quality (Gulia et al., 2020). Landscape species are bioindicators for accumulating heavy metals that their bodies absorb to heavy metal pollution (Markert et al., 1999; Nowak et al., 2018). However, it has not been precisely determined which species are the most suitable biomonitors (Weinstein & Davison, 2003; Aricak et al., 2019). Landscape plants are likely to be suitable biomonitors because it has been exposed for a long time to heavy metal pollution according to their location (Isinkaralar et al., 2017; Bharti et al., 2018; Ghafari et al., 2021). Therefore, it will take almost how long the heavy metal concentration obtained through research has been accumulated in urban air pollution (Aboal et al., 2010; Leghari et al., 2019).

Some species (mosses, lichens, and plants) must possess certain qualities as a biomonitor (Motyka et al., 2020; Ghennam et al., 2021; Mukhopadhyay et al., 2021). The first of these features is that the selected organisms should have the ability to accumulate heavy metals, but they should not die immediately due to the low concentration values of heavy metals (Turkyilmaz et al., 2018; Isinkaralar & Erdem, 2022). They should live stably in the region where they will be sampled. Also, they should be found plentifully in the study area, and it should be possible to test them when desired due to being easy to obtain (Wannaz et al., 2012). A sufficient amount of organs or tissues must be supplied to analyze them to find a correlation between the heavy metal concentration in biomonitor organisms and the heavy metal concentration in the environment (López-Luna et al., 2009; Mahapatra et al., 2019; Kováts et al., 2021). Many heavy metals such as Cd, Cr, and Zn are dissolved during corrosion and transport in the atmosphere by weather and climate events (Yoshino et al., 2021). Although heavy metal sources are known at the urban scale, it is estimated that there are also emissions from conventional sources (Gholizadeh et al., 2019; Jeong et al., 2020). Therefore, there is still no clear information about heavy metals' atmospheric transport and accumulation (Liu et al., 2018).

Regarding these properties, it was evaluated that landscape plants were good biomonitors, and many studies were conducted on them to determine regional heavy metal deposition (Bajpai et al., 2009; Paoli et al., 2019; Turkyilmaz et al., 2020). Trees' organs are commonly preferred for environmental pollution biomonitors due to accumulation in a wide range of air pollutants (Prado et al., 2016; Khosropour et al., 2019). Biomonitoring with trees offers an excellent and affordable method for detecting and assessing environmental pollution (including atmospheric deposition), especially in developing countries or remote areas (Isinkaralar, 2021; Savas et al., 2021). The biggest problem encountered in biomonitor applications is that finding the determined heavy metal level in a species is complicated (Karimi et al., 2020; Karacocuk et al., 2022). There are many changing biological factors and variable parameters in a clean and uncontaminated region as a reference species because it is tough to find the same tree with the same age, height, and characteristics. Studies have reported tree species' absorption of nutrients and heavy metals in the heavy traffic region (Tang et al., 2019). At the same time, they are not found in their natural environment or are present in tiny amounts. Another issue, even when comparing a species, is the accumulation in the organs of the species facing heavy traffic. The expansion in the organs away from the traffic is different. Different collections are proportional to their genetic structures and adsorbing capacity for other species. It causes the reliability of the obtained that the plants' organ and if there is tree ring have been accumulated precisely air pollutants. Therefore, some species become awesome biomonitors due to their biological structure to atmospheric heavy metal deposition.

This landscape plant biomonitoring study aims to assess atmospheric Cd, Cr, and Zn pollution into their organs and washing conditions. The accumulation levels of 14 species grew in the same periods and conditions due to the exposure of these species, which are the most used in the landscape. The exhaust gases originating from vehicle traffic and the wear of parts such as engines and tires were evaluated with air pollution. In addition, logistics services are provided intensively by ships at the port located close to that region in Mersin, Türkiye. Among these species, it aimed to identify how heavy metal accumulation can be easily seen in their organs.

2 Materials and Methods

2.1 Sampling Area

The study area (36°47′46.0″N-34°37′46.9″E) is a large park located by the coast in the city center of Mersin. It is a port city located in the Mediterranean region, where population, tourism, and ship traffic are intense in Türkiye. Mersin is the 11th largest city, an important tourism and port trade area in Türkiye, and it has almost 1,900,000 population.

2.2 Sample Collection

Tree leaves and barks were collected from 14 of the species frequently used for comparison in landscape plants that grow in areas with heavy traffic. They were collected from last year's shoot, the 1-year-old part, towards the end of the vegetation season in October 2021 and were brought to the laboratory after being bagged with several sample IDs (Table 1). They were placed in polyethylene containers for transport to the laboratory and were stored at – 10 °C until preparation and chemical analysis of samples.

2.3 Preparation and Chemical Analysis

Samples were dissected into organs without any metal tools. Processes are divided into two groups washing and non-washing. Some of the bark and leaves were washed, and all samples were labeled after rinsing with distilled water. The organs were coded considering the washing process, such as washed leaf "WL," unwashed leaf "UWL," washed bark "WB," and unwashed bark "UWB," and wood samples were also shown with "WD" codes. They were taken from the roadside and were kept at room temperature until dry and dehumidified. Then, the samples were ground into powder (weighed 0.5 g landscape species) and placed in special tubes designed for microwave-supported acid digestion by the United States Environmental Protection Agency (US EPA) 3052 method (US EPA, 1996). Ten milliliters of 65% nitric acid (HNO_3) was added to the samples, and they were digested in the microwave at 280 PSI 180 °C for 20 min. After the first step, the tubes were cooled down following their removal from the microwave; the next step was adding 9 mL 30% hydrochloric acid (HCl) and 3 mL HNO_3 to it, then putting the mixture in the microwave. Finally, distilled water was added to fill up to 50 mL. All reagents of the highest purity grade were purchased for sample preparation and chromatographic analysis by Suprapur®, Merck, Germany. Then, the element concentrations in the samples filtered through the filter paper were read at the appropriate wavelengths in the inductively coupled plasma optical emission spectrometry (ICP-OES system by Spectroblue, SPECTRO, Analytical instruments GmbH, Germany). Finally, the concentrations of the study elements were determined after multiplying the obtained values with the dilution factor.

Table 1 The sample ID number in landscape species

Selected species	Sample ID
Cupressus sempervirens L	SP1
Thuja occidentalis L	SP2
Citrus reticulata Blanco	SP3
Platanus orientalis L	SP4
Prunus cerasifera Ehrh	SP5
Photinia serrulata Lindl	SP6
Eucalyptus camaldulensis Dehnh	SP7
Chamaecyparis lawsoniana (A. Murr.) Parl	SP8
Laurus nobilis L	SP9
Cercis siliquastrum L	SP10
Schinus molle L	SP11
Pyracantha coccinea M.J.Roemer	SP12
Acer hyrcanum F. et Mey	SP13
Pinus brutia Ten	SP14

2.4 Statistical Analyses

Descriptive statistics analyses were evaluated with SPSS packaged software Windows (IBM SPSS Statistics, version 22.0); one-way ANOVA and Duncan's test were applied to assess the accumulation of Cd, Cr, and Zn elements in selected landscape species. The *F* value, error rate, and thus the difference of the factors were determined at the 95% confidence level. The obtained results were interpreted after simplifying and tabulating.

3 Results

3.1 Cr Concentrations

The organ changes were evaluated separately. Therefore, the average values of the Cr concentrations, which are among the most critical elements in terms of human and environmental health, based on species and statistical analysis results, are given in Table 2.

When the variance analysis results of the change of Cr concentrations in the species according to the organ age and location (position, direction, and washing) are examined, it is statistically significant at the 99.9% confidence level in all the sites. When the mean values and Duncan test results are concerned, it is seen that the values obtained in wood in all species

Table 2 The accumulation of the Cr (ppb) concentration in landscape plants

Species	Leaf and bark are classified by washing process					*F* value
	UWL	WL	UWB	WB	WD	
SP1	2923.7 Df	2448.5 Bi	3199.2 Ek	2752.8 Ce	960.6 Ae	273.4***
SP2	2007.5 Ec	1934.2 Df	1327.6 Cef	1197.4 Dc	1024.9 Af	3099.8***
SP3	1524.4 Db	1387.6 Cb	1364.8 Cf	1087.4 Bb	942 Acd	803***
SP4	3267.9 Dh	2376.5 Ch	1126.7 Bc	1091.3 Bbc	898.2 Ab	3510.6***
SP5	3140.9 Eg	2926.8 Dk	2854.2 Ci	1160.1 Bbc	945.2 Acde	9636.9***
SP6	3173.2 Dg	2960.8 Ck	1692.8 Bh	4234.2 Eg	1488.8 Ag	3088.5***
SP7	1217.1 Ca	1551.8 Dd	1029.2 Bb	1067.7 Bb	935 Ac	293.3***
SP8	6400.4 Ej	2053.6 Bg	3091.6 Cj	3280.4 Df	903 Ab	10,389.1***
SP9	2337.8 Ee	1175.1 Ba	1535.4 Dg	1302.8 Cd	856 Aa	721.6***
SP10	2148.1 Ed	1815.6 De	964.4 Ca	871.7 Aa	907.3 Bb	2854***
SP11	5130.7 Ei	1143.6 Ba	1361.7 Cef	3349.8 Df	860 Aa	4449.3***
SP12	1974.8 Ec	1470.6 Dc	1100 Cc	957.2 Ba	857.8 Aa	2097.3***
SP13	3321.5 Eh	2538.5 Dj	1220.3 Cd	1106 Bbc	954.8 Ade	29,318.9***
SP14	1521.2 Cb	1840.4 De	1321.5 Be	1326.2 Bd	909.2 Ab	1411.8***
F value	3721.7***	1920.8***	3468.4***	1072.7***	806.8***	

Uppercase letters: horizontal direction for each variable

Lowercase letters: vertical direction for each variable

***Significance at $p<0.001$

except SP10 are in the first group. Apart from this, it is noteworthy that the concentrations obtained were in the UWL of all species except SP7 and SP14. They are higher than the concentrations determined in the WL. The difference between WL and UWL is relatively high in some species, such as SP8 and SP11. In addition, Cr concentrations were higher in the barks, which are generally not washed. The highest values were obtained for SP8 in UWL, SP5 and SP6 in WL, SP1 in UWB, and SP6 in WB and WD. Therefore, it is seen that the highest values are in SP8 and SP6. In addition, it is noteworthy that although the Cr concentration in organs is quite variable based on species, the Cr concentrations obtained in WD are only 1488.8 ppb in SP6, and they vary in a very narrow range as 856.1–1024.9 ppb.

3.2 Cd Concentrations in Species

The information about Cd concentration determination in various species is given on organ and washing status in Table 3.

As a result of the analysis of variance, it was determined that the changes in the Cd concentration were statistically significant ($p<0.001$) in all species and based on species in all years. The variation of Cd concentration in all organs based on species was statistically significant at the 99.9% confidence level ($p<0.001$), while the interpretation based on organs was statistically insignificant ($p>0.05$) in SP7 and SP13. When the values are examined, the concentrations obtained for SP3, SP5, SP6, SP7, SP8, and SP13 are below the detectable limits in the WD. In addition, SP13 was below the detectable limits in barks and wood. Also, S14 has showed undetectable values in UWL, WL, and WB. When the changes of Cd concentration on an organ basis are examined, the values obtained were in WD excluding S9 and S11. They are in the first groups as a result of the Duncan test. Notwithstanding, it is seen that only the values obtained in SP12 are pretty high and the highest values among all values are obtained in S12. In addition, there is only the value obtained in the bark that is not washed bark in SP4. Apart from this, the Cr concentration in organs of all species varies between 94.4 ppb and 175.5 ppb.

3.3 Zn Concentrations

The organ changes were separately evaluated, and the average values of the Zn concentrations based on species and statistical analysis results are given in Table 4.

When the variance analysis results of the change of Zn concentrations in the species according to the organ age are examined, it is seen that it is statistically significant at the 99.9% confidence level in all the locations based on age and in all ages based on

Table 3 Variation of the Cd (ppb) concentration in the landscape plants for years

Species	Leaf and bark are classified by washing process					*F* value
	UWL	WL	UWB	WB	WD	
SP1	149.6 Cfg	139.6 Bf	161.9 Dg	160.7 Dg	100 Aa	130.5***
SP2	147.3 Cef	141.1 Bf	164.2 Dg	175.5 Eh	103.53 Aa	295.4***
SP3	126.1 Ad	137.6 Bf	131.7 ABe	152.4 Cf	-	25.2***
SP4	147.2 Cef	138.2 Bf	151.4 Cf	236.6 Dj	116.60 Ab	918.9***
SP5	148.4 Cefg	100.4 Ab	161.4 Dg	126.1 Bcd	-	282.1***
SP6	111 Ab	133.1 Be	109.8 Ab	138.6 Ce	-	76.8***
SP7	109 b	107.1 c	115.7 c	112.1 a	-	3.6 NS
SP8	154.1 Cg	146.2 Bg	125.5 Ad	128 Ad	-	34.7***
SP9	142.9 De	94.4 Aa	118.2 C	120.4 Cbc	104.2 Ba	193.3***
SP10	117.6 Bc	98.6 Aab	113.4 Bbc	131.6 Cd	102.6 Aa	64.1***
SP11	211.9 Bh	666.9 Eh	561.2 Di	193.1 Ai	354.8 Cc	17,285.8***
SP12	127.4 Bd	118.4 Ad	173.1 Dh	156.3 Cfg	118.4 Ab	113.9***
SP13	95.3 a	96.2 ab	-	-	-	0.1 NS
SP14	-	-	100.1 Aa	-	116.5 Aab	61.1**
F value	202.8***	9646.1***	5560.4***	244.7***	3531.6***	

Uppercase letters: horizontal direction for each variable

Lowercase letters: vertical direction for each variable

NS, no significant difference. **Significance at $p<0.01$,***significance at $p<0.001$. -, below the limit value

Table 4 The accumulation of the Zn (ppb) concentration in landscape plants

Species	Leaf and bark are classified by washing process					*F* value
	UWL	WL	UWB	WB	WD	
SP1	8950 Db	6270 Ba	9690 Ef	7330 Cd	2780 Ac	32829.4***
SP2	11090 Ee	9250 Dc	5550 Bb	4920 Ab	6100 Cj	8908.8***
SP3	8210 Da	9590 Ed	5260 Ca	3180 Aa	3850 Bg	6373.2***
SP4	15910 Ej	11800 De	7200 Bd	8660 Cf	4880 Ah	5382.1***
SP5	13580 Dg	11820 Ce	31280 Em	9710 Bh	6120 Aj	32414.3***
SP6	11350 Bf	13700 Dh	11680 Ch	30280 En	3700 Af	39889.3***
SP7	1036 0Cd	11620 De	8150 Be	8170 Be	3010 Ad	5722.6***
SP8	39940 En	16390 Bj	17800 Cj	18330 Dl	2530 Aa	24429.3***
SP9	9260 Ec	8210 Db	6530 Bc	7120 Cc	2640 Ab	10509.7***
SP10	15340 Bi	16430 Dj	22380 Ek	12610 Aj	15,710 Cl	1535.1***
SP11	23650 El	12280 Bf	14990 Di	14100 Ck	9840 Ak	1491178.7***
SP12	29620 Em	28900 Dk	23400 Cl	19280 Bm	6150 Aj	13937.4***
SP13	18760 Ek	15410 Di	10160 Cg	8840 Bg	5000 Ai	17965.8***
SP14	14170 Eh	13180 Dg	8150 Be	9900 Ci	3350 Ae	7216.1***
F value	25140.3***	5296.4***	17410.8***	39731.1***	9480.4***	

Uppercase letters: horizontal direction for each variable

Lowercase letters: vertical direction for each variable

***Significance at $p<0.001$

site. As a result of the analysis of variance, it was determined that the changes in Zn concentration in all species and based on species in all organs were statistically significant at the 99.9% confidence level ($p<0.001$). When the mean values and Duncan test results were examined, the highest values were obtained for SP12 (28,900 ppb) and SP10 (16,430 ppb) in WL, SP5 (31,280 ppb) in UWB, SP6 (30,280 ppb) in WB, and SP10 (15,710 ppb) in WD. The highest Zn concentrations are obtained in SP12, SP10, and SP8, while the lowest concentrations are obtained in SP1, SP3, and SP9. As a result of the Duncan test, the concentrations obtained in the WD were in the first groups except for SP2, SP3, and SP10, while the highest concentrations were obtained in the UWL in half of the species.

Figure 1 indicates the accumulation of heavy metals in general, regardless of organ separation

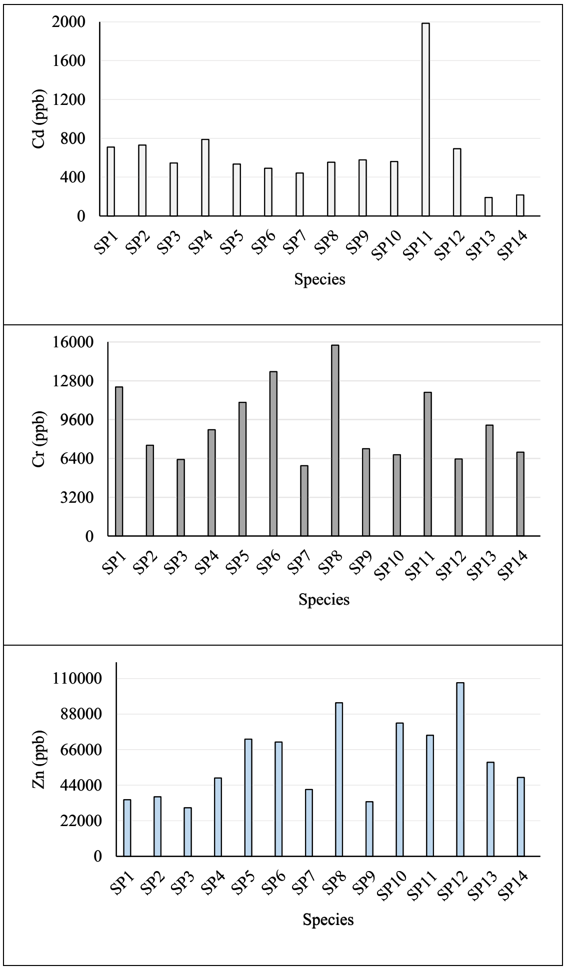

Fig. 1 Overall accumulation rates of Cr, Cd, and Zn among landscape plants (from SP1 to SP14)

and washing. The highest values are obtained in Zn with SP8 (94,990 ppb), SP6(70,710 ppb), and SP10 (82,470 ppb), although the lowest values were acquired with SP3 (30,090 ppb), SP9 (33,760 ppb), and SP1 (35,020). On the other hand, the values obtained in Cr are relatively low, and the highest values were gained with SP8 (15,727 ppb), SP6 (13,547 ppb), and SP1 (12,282 ppb), although the lowest values were acquired with SP7 (5799 ppb), SP3 (6304 ppb), and SP12 (6358 ppb). Finally, the values in Cd are due to the scarcity of sources in the environment in the release of Cd from high to low to the atmosphere as follows SP11 (1985 ppb), SP4 (788 ppb), and SP2 (730 ppb) although the lowest values were SP13 (191 ppb), SP14 (216 ppb), and SP7 (443 ppb).

4 Discussion

The study was carried out to monitor the changes of Cr, Cd, and Zn concentration in the recent past. Changes in three organs, leaf, bark, and wood were examined based on organ age, location, and direction. Many studies have been carried out on heavy metal concentrations in plants (Turkyilmaz et al., 2019; Isinkaralar, 2022). Although these elements have been the subject of heavy metal concentration studies in general, these studies mainly concentrated on heavy metals (Cetin et al., 2021). The main factors for the prominence of the studies on these elements could be the fact that they can be toxic and carcinogenic even at low concentrations. Cr, Mn, and Zn are among the most toxic heavy metals in their potential toxicity and exposure to living organisms. In addition to nasal discharge, nosebleeds, itching, and perforations in the upper respiratory tract, asthma attacks can also be seen in people with allergic reactions to chromium. It shows that the elements subject to the study have significant differences in their organ concentrations. Numerous studies were conducted for atmospheric heavy metal on the mosses, lichens, and plants (Ghoma et al., 2022). Harmens et al. (2010) have reported that emissions and depositions of heavy metals on mosses were collected in Europe from 1990 to 2005. The accumulation levels in different countries have been found and proved effective biomonitors to deposition to identify areas at risk from atmospheric heavy metals deposition. There are studies in which lichens are used as biomonitors. Boamponsem et al., (2010) determined atmospheric heavy metal deposition on widespread lichen species in the Tarkwa, Ghana. They studied gold mining areas which were found both anthropogenic and natural sources of heavy metals. Apart from the studies with moss and lichens, plants came to the fore (Isinkaralar & Erdem, 2021a, 2021b). Liang et al., (2017) have studied heavy metal deposition on twelve plant species leaves. They were collected from seven areas, and the correlation of their washing process and soil and atmospheric accumulation was evaluated. They reported that *Nerium indicum* and *Platanus acerifolia*, *Pittosporum tobira*, and *Cedrus deodara* were suitable for measuring Cu, Zn, Cd, and Pb pollution, respectively. Nadgórska–Socha et al., (2017) have examined heavy metal concentrations on 4 plants, that is, *Taraxacum officinale*, *Plantago lanceolata*, *Betula pendula*, and *Robinia pseudoacacia* grown up in Dąbrowa Górnicza, Poland. Their study exhibited the Air Pollution Tolerance Index (APTI) of heavy metals as follows: *P. lanceolata* (11.9); *R. pseudoacacia* (14.2); *B. pendula* (19.5); *T. officinale* (30.97). In these studies, plants used as biomonitors accumulate heavy metals in their bodies, and their analyses can give an idea of the level of heavy metal pollution in organs (leaves, branches, seeds, bark, wood, inner bark, and outer bark) (Koc, 2021; Sevik, 2021). However, the contamination and accumulation of heavy metals in the plant body are closely related to environmental conditions (Cetin et al., 2020). Their contamination in plants also has a significant relationship with air humidity and precipitation. Moreover, the accumulation of heavy metals in the plant is also related to the habitat and development of the plant. Plant growth is affected by environmental conditions. A study of landscape plants was carried out to determine Ni, Cd, and Zn pollution on *Prunus ceracifera*, *Aesculus hippocastanum*, *Tilia tomentosa*, *Fraxinus excelsior* and *Acer platanoides* that were collected from Kastamonu, Türkiye, by Sevik et al., (2019). They reported that landscape plants accumulate toxic metals from vehicular emissions (leaves, seeds, and branches) in their organelles. Environmental conditions consist of a combination of edaphic and climatic factors, and these conditions affect both plant growth and the contamination of the plant body with heavy metals (Sevik et al., 2020). In addition to plant development, the genetic structure of the plant is also influential in the process of contamination and accumulation of heavy metals. Genetic structures and environmental conditions shape all phenotypic characters of living things. Therefore, the phenotypic characters and growth performances of individuals of the same species can show differences even though the environmental conditions are similar. Values obtained in leaves and bark are highly variable to monitor Cd, Cr, and Zn pollution. The lowest values were obtained in wood, and the variation in wood was minimal. Since the samples were collected in a restricted area, the soil structure is relatively homogeneous. In this case, it can be said that Cr is taken into the plant from the soil rather than the air. It is noteworthy that the concentrations obtained in the unwashed leaves, in general, are higher than the concentrations determined in the washed leaves. In this case, it can be said that particulate matter in the air is contaminated with Cr. SP8 and SP6, where the highest values are obtained, can be used to reduce Cd, Cr, and Zn pollution. The values obtained in woods are usually below the limit or at the lowest. Therefore, it can be said that Cd is taken from the soil rather than the air. It is seen that the Cd concentration is relatively high only in SP11 and varies in a very narrow range in other species, both based on species and organ. In this case, it can be said that only SP11 is the suitable type that can be used both for monitoring and reducing the Cd concentration in the air. The high Cd concentration in only one of the 14 species used in the study shows the necessity of including many different heavy metal studies. Scarcely, many more unknown sources of air pollution have been encountered on an urban scale for various reasons. Climate, port city, and variable atmospheric conditions due to traffic (such as engine and tire wear), instability of emissions, and many other factors add to the uncertainty of the data.

5 Conclusion

Air pollution is rapidly emerging in cities, and it is impossible to measure or monitor (active or passive measurement) all deposition pollutants for many reasons. First, the experimental approach and the quantitative situation are determined to evaluate urban air pollution and its effects. Then, there is a model approach with the possibilities that can be established accordingly. In the experimental procedure, determining and increasing the number of biomonitoring species that can be used will increase the accuracy of the results. To analyze the species that can be used to determine the regional air quality, comparing the same species from an uncontaminated area (such as traffic, industry, agricultural activities, etc.) and a densely populated place with samples taken from different points does not provide quantitative data. In this study, the Cr concentrations of *Chamaecyparis lawsoniana* (A. Murr.) Parl. and *Photinia serrulata* Lindl. leaves and barks that can sustain for many years were determined according to several kinds of landscape plants. The study results showed that the heavy metal concentrations changed significantly depending on the spatial and temporal variability (wet and dry deposition, species, organs, washing, and exposure to emission type-frequency). *Schinus molle* L. and *Pyracantha coccinea* M.J.Roemer are suitable types that can be used solely as biomonitors and to reduce the Cd and Cr concentration. The *Chamaecyparis lawsoniana* (A. Murr.) Parl. is a convenient biomonitor for sequestering Zn pollution and it might be recommended for biomonitoring research in the future.

Author Contribution Kaan Isinkaralar: raw material collection, processing analysis, data interpretation, writing original draft, data curation. Ismail Koc: processing analysis and interpretation. Ramazan Erdem: formal research, review and editing. Hakan Sevik: conceptualization, software.

Availability of Data and Materials The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Declarations

Ethics Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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