Environment, Development and Sustainability (2020) 22:2385–2398
https://doi.org/10.1007/s10668-018-0296-7

Variation of heavy metal accumulation in certain landscaping plants due to traffic density

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Received: 3 January 2018 / Accepted: 12 November 2018 / Published online: 15 November 2018

Abstract

Air pollution is one of the biggest problems of urban environments today. Heavy metals are particularly important in terms of components that pollute the air. This is due to the reason that heavy metals can stay in nature for a long time without being disintegrated, and their concentration in the environment is constantly increasing. They also tend to bioaccumulate. Therefore, determination of the heavy metal concentration is crucial for identifying high-risk areas and the level of risk. Plants are generally used as biomonitors for determining heavy metal concentration in the air. Determination of heavy metal concentrations in plants is crucial in determining the ability of plants to remove heavy metals from the air, and thus being used as a means of increasing air quality, as well as monitoring air quality. The aim of this study was to determine the variation of different heavy metal concentrations depending on traffic density in certain landscape plants collected from areas where traffic density is at different levels. For this purpose, leaf samples of *Salix babylonica, Robinia pseudoacacia, Sophora japonica,* and *Aesculus hippocastanum*, which are frequently used in landscaping studies, were collected from individuals where there was dense traffic, less dense traffic, and almost no traffic, and the quantities of Pb, Cu, Ca, Mg, Cd, Cr, Ni, Fe, Mn, and Zn were determined by heavy metal analysis. Based on the results, the highest mean values of Cd, Ni, and Zn were found in *S. babylonica*, highest mean values of Pb and Mn were found in *A. hippocastanum*, and those of other elements were found in *S. japonica*. In areas with a high traffic density; the highest values of Cd, Ni and Zn were found in *S. babylonica* and the highest values of Cu, Mg, Cr, Fe and Mn were found in *S. japonica*. In areas with high traffic density, only the highest value of Pb was found in *A. hippocastanum* and the highest value of Ca was found in *R. pseudoacacia*. Based on these results, it can be concluded that *S. babylonica* and *S. japonica* are good bioindicators.

Keywords Bioindicator · Heavy metal · Urban traffic density · Landscape plant · Air pollution

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1 Introduction

Today, especially in developing countries, urbanization is increasing rapidly and it is estimated that 60–90% of the world population will be living in cities by 2030. In European countries, more than two-thirds of the total population and in our country about 3/4 of the population live in cities, and this ratio is constantly increasing (Sevik et al. 2017a). Increasing population and industrialization resulted in air pollution, and air pollution has increased in some cities to levels that threaten human health and became one of the most important issues of today (Turkyilmaz et al. 2017). Every year, thousands of people are affected by air pollution, and millions of people around the world lose their lives due to causes related to air pollution. The intensification of air pollution in urban centers poses a greater risk especially for people with various health problems (Isinkaralar et al. 2017; Cetin et al. 2017b, c). Heavy metals are particularly important due to their inherent nature that contributes to air pollution. Heavy metals do not disintegrate in nature and do not disappear. They also tend to bioaccumulate. Therefore, the determination of heavy metal concentrations is of great importance in determining the high-risk areas and the level of risk (El-Hasan et al. 2002). Plants are commonly used as biomonitors in monitoring heavy metal concentrations (Tomasevic and Anicic 2010; Petrova et al. 2014; Ozel et al. 2015; Ozturk and Bozdogan 2015; Trujillo-González et al. 2016; Delgado-García et al. 2013; Trujillo-González et al. 2011; Liang et al. 2016, 2017). Taking into consideration the environmental and social benefits of plants (reducing air pollution, noise, erosion, etc.), using plants within and around cities is employed as a strategy to improve quality of life in urban areas, and the visual and aesthetic value of people's living environments (Sevik et al. 2017a, b). The presence of plants in city centers is considered as a sign of urban quality and the livability of the constructions (Cetin 2017). The environments that contain plants help increase the quality of life for people living in cities by reducing air pollution and noise (Cetin and Sevik 2016a, b). In addition, plants perform many functions such as being an economic resource, reducing wind speed, and supporting wildlife (Kaya 2009; Kaya et al. 2009; Cetin et al. 2010, 2018; Cakir et al. 2016).

In addition to the ecological, economical, and social benefits of plants, they are known to help improve air quality and reduce air pollution (Sevik et al. 2017a, b; Turkyilmaz et al. 2018a). However, not every plant has the same effect in absorbing airborne heavy metals that are particularly significant in air pollution. Studies conducted so far reveal that different plants have different levels of potential for accumulating different heavy metals. Therefore, using plants as biomonitors as well as their effective use in removing heavy metals from air can only be possible by determining the capabilities of different plants in accumulating different heavy metals.

The aim of this study was to determine the variation of different heavy metal concentrations depending on traffic density in certain landscape plants collected from areas where traffic density is at different levels.

2 Materials and methods

2.1 Sample collection and tree types

In this study, 4 plant species (*Salix babylonica*, *Robinia pseudoacacia*, *Sophora japonica* and *Aesculus hippocastanum*) x 3 trees (from each species) x 3 locations (high, medium and low traffic) x 3 replications and a total of 108 samples were studied. Materials collected from Ankara city center were used in the study. Ankara is the capital of Turkey, has a population of 5,346,518 as of 2016 (URL1 2017), and is one of the largest cities in Turkey. Kızılay-Ulus route, where samples were collected, is an area with high traffic density with a motorway of four lanes in each direction and a total of eight lanes. To be used in the study, 1 kg of leaf samples were collected from *S. babylonica, R. pseudoacacia, S. japonica,* and *A. hippocastanum* species, which are commonly used in landscaping. Leaf samples were collected during vegetation season from areas with high traffic density, low traffic density, and areas with no vehicle entry for at least a radius of 50 m and were brought to the laboratory.

2.2 Short description of landscape plants

2.2.1 *Salix babylonica*

Salix babylonica is grown as ornamental plants in parks and gardens. It is a pleasant tree with a sagging form, capable of making 10–15 m length (Karaca and Kuşvuran 2012; Bıçakçı et al. 2014; Özay 1997).

2.2.2 *Robinia pseudoacacia*

They are the trees that can reach up to 25 m and can live for 100 years on average. The shape of the leaves is elliptical or egg-shaped. The number of leaflets generally ranges from 7 to 19. The upper surfaces of the leaves are light green, and their lower surfaces are gray–green (Keskin 2007).

2.2.3 *Sophora japonica*

Sophora japonica is a species with the ability to make 20–25 m length on average. The leaves of the leaves are in the size of 15–20 cm. The number of short-stemmed leaflets is between 7 and 17. The upper surfaces of the furry leafy people are bright dark green, while the lower surfaces are bluish green (Bird 2013; Kaya 2014).

2.2.4 *Aesculus hippocastanum*

Aesculus hippocastanum is a plant species that is known with splendid view over the world. It can reach up to 20–30 m in height. The top crown is in a wide and flat form because the crown of the tree is flat and columnar and the branches are frequent. Forms of radial leaves are 5–9 leafy palmate structures. They are long-stalked and have a smooth structure on the leaves (Özcimder 2014).

When the traffic density is determined, the road width and vehicle density are taken into account. The areas where the traffic is concentrated are located in the Ankara city center Ulus-Kizilay road, and there are four lines in the direction of going to the destination and at least 20 h of traffic flow. The area where the traffic is less intense is the road connection routes where the traffic is intense, and the distance between the four lines departures and the 4 lines arrival is totally eight lines. The areas where there is no traffic are the areas where there is no space for transporting at least 50 m to the same area.

Within the scope of the study, approximately 1 kg of leaf samples are collected from each of the three trees from each branch. The samples are collected from the trees in the middle isle. (The isle has a green area that is 1 m width between the lanes and has plants and grass.) A total of 36 branches were collected from four species in total, and a total of 108 samples were studied by three repetitive trials.

The trees are located in the middle of the road, so their distance to the road is less than 1 m. The trees where the samples are collected are 15–20 m in length; these branches were collected and used in the study due to the fact that these trees were more exposed to traffic density.

The mechanism of heavy metals acquisition and accumulation in plants is very complicated, and there is limited information about the transport of heavy metals taken from air into the plant. This mechanism is shaped by the influence of many scalar factors such as plant tour, leaf structure, stoma structure, and plant–heavy metal interaction (Shahid et al. 2017). However, the number of studies done in this regard is very limited; the difference in the accumulation potential of heavy metals in plants cannot be commented on.

The study was carried out on growing trees in the same area during a vegetation season. Therefore, the heavy metal accumulation on the leaves reflects the accumulation of 5-month period between April and August. The aim of the study is to compare the accumulations that have come to the fore depending on the traffic density. However, it is not possible to determine in which stage the accumulation of soil and water occurred. Therefore, the accumulation of heavy metals in soil and in the water has not been studied, the study has only been designed to compare the accumulation of heavy metal in the field, and no discussion can be made in the study area when there is no relevant study on metal accumulation in soil and water. All of the sample location maps are shown in GIS work in Fig. 1.

Fig. 1 Showing the sample location maps in Ankara city center

2.3 Analytical method

The samples were moved in large-sized cartons in which they could breathe in the closed environment, during which time the samples were not exposed to air pollution from the outside, and they began to dry in normal conditions. The samples, which were classified in the laboratory and put into labeled glass containers, were left to stand for 15 days until they were room-dried, and then, the samples were dried in an incubator at 50 °C for 1 week. Experiments were initiated on dried samples on the same day for heavy metal analysis.

2.4 Identification of heavy metals

Two grams of the dried samples were weighed and placed in 10 ml of concentrated HNO_3 at room temperature for 24 h and then boiled for 1 h at 180 °C. Then, 20 ml of distilled water was added to the solution, and the solution was filtered through a 45-µm filter paper. In the solutions obtained from the filtrate, heavy metal analyses were performed for Pb, Cu, Ca, Mg, Cd, Cr, Ni, Fe, MN, and Zn with GBC Integra XL-SDS-270 ICP-OES instrument. The detection limits used in the study were Pb > 0.377 ppb, Cu > 0.639 ppb, Ca > 0.00208 ppm, Mg > 0.00758 ppm, Cd > 0.063 ppb, Cr > 0.311 ppb, Ni > 0.171 ppb, Fe > 0.00068 ppm, Mn > 0.00015 ppm, and Zn > 0.00634 ppm.

2.5 Statistical analyses

The obtained data were evaluated with SPSS package software, variance analysis was applied to the data, and homogeneous groups were obtained by applying the Duncan's test to the values showing statistically significant differences in at least a 95% confidence level. The obtained data were simplified, represented in tables and interpreted.

Table 1 Variation in heavy metal amounts depending on plant species

	Salix babylonica	*Robinia pseudoacacia*	*Sophora japonica*	*Aesculus hippocastanum*	*F* val
Pb (ppb)	8.093 a	12.994 b	14.544 bc	17.904 c	10.792***
Cu (ppb)	49.364 a	36.957 a	155.222 b	72.515 a	6.817**
Ca (ppm)	1.534 a	2.858 b	3.448 b	2.057 a	9.558***
Mg (ppm)	0.423 a	0.468 a	0.701 b	0.471 a	55.199***
Cd (ppb)	84.935 b	5.160 a	4.737 a	5.200 a	3.812***
Cr (ppb)	24.151 a	21.233 a	40.304 b	28.928 a	6.078***
Ni (ppb)	12.048 b	8.015 a	5.473 a	4.151 a	6.864**
Fe (ppm)	8.495 a	15.206 a	34.691 b	19.497 a	9.082***
Mn (ppm)	4.713 ab	4.084 a	5.557 b	6.977 c	7.758***
Zn (ppm)	14.084 c	5.282 b	5.171 b	1.540 a	18.699***

The letters a, b, c, etc. means according to Duncan's test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

**Significant at 0.01 level

***Significant at 0.001 level

3 Results

The accumulation amounts of heavy metals based on species were calculated in the studied species, variance analysis and Duncan's test were applied to the obtained data, and the results are given in Table 1.

When the analysis results are examined, it is seen that there is a statistically significant difference among the species with respect to all the heavy metals subject to the study at a confidence level of at least 99%. The highest average values of Cd, Ni, and Zn were found in *S. babylonica*, highest average values of Pb and Mn were found in *A. hippocastanum*, and other elements were found in *S. japonica*. Average values of heavy metal quantities based on traffic density, variance analysis results, and Duncan's test results are presented in Table 2.

When we look at Table 2, we see that the accumulation of all heavy metals studied except Mg and Cd shows a statistically significant difference with respect to traffic density at a confidence level of at least 95%. In all heavy metals, the highest values were obtained from areas with high traffic density. The heavy metal quantities of studied species with respect to traffic density, variance analysis results, and Duncan's test results are shown in Table 3.

When we look at Table 3, we see that metal quantities significantly change in all species depending on traffic density for Pb, Cu, Ca, Ni, Fe, Mn, and Zn at a confidence level of at least 95%. In *R. pseudoacacia* and *A. hippocastanum*, Mg levels show no significant variation, whereas in *A. hippocastanum*, Cr levels show no significant variation with respect to traffic density (95% confidence level). The change in Cd amounts with respect to traffic density is only statistically significant in *S. babylonica* at a confidence level of 99.9%, and

Table 2 Variance in heavy metal quantities based on traffic density

Metals	Traffic density			*F* val
	No	Middle	Dense	
Pb (ppb)	9.492 a	13.765 b	16.895 b	9.730***
Cu (ppb)	36.351 a	71.785 a	127.408 b	5.731**
Ca (ppm)	1.812 a	2.449 ab	3.162 b	5.992**
Mg (ppm)	0.506 a	0.480 a	0.560 a	1.406 ns
Cd (ppb)	10.060 a	29.588 a	35.376 a	1.295 ns
Cr (ppb)	21.365 a	32.163 b	32.435 b	3.690*
Ni (ppb)	4.160 a	6.588 a	11.518 b	11.223***
Fe (ppm)	9.396 a	22.663 b	26.358 b	5.903**
Mn (ppm)	4.298 a	5.393 ab	6.308 b	5.268**
Zn (ppm)	2.818 a	7.135 ab	9.605 b	5.060*

The letters a, b, c, etc. means according to Duncan's test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

ns not significant

*Significant at 0.05 level

**Significant at 0.01 level

***Significant at 0.001 level

Table 3 Change in heavy metal quantities according to plant species and traffic density

	Salix babylonica	*Robinia pseudoacacia*	*Sophora japonica*	*Aesculus hippocastanum*
Pb (ppb)				
No	5.006 a	8.856 a	9.526 a	14.580 a
Middle	8.953 b	13.753 b	14.813 ab	17.540 b
Dense	10.320 b	16.373 b	19.293 b	21.593 c
F val	17.369**	13.368**	9.760*	10.281*
Cu (ppb)				
No	35.400 a	22.533 a	31.260 a	56.213 a
Middle	43.146 b	31.353 b	130.853 b	81.786 b
Dense	69.546 c	56.986 c	303.553 c	79.546 b
F val	104.923***	83.110***	759.125***	24.424**
Ca (ppm)				
No	1.372 a	1.145 a	2.930 a	1.803 a
Middle	1.548 b	2.884 b	3.056 b	2.308 c
Dense	1.682 c	4.546 c	4.360 c	2.060 b
F val	748.539***	29,528.679***	3144.665***	1346.747***
Mg (ppm)				
No	0.419 a	0.443 a	0.669 a	0.456 a
Middle	0.382 a	0.479 a	0.630 a	0.468 a
Dense	0.467 b	0.482 a	0.804 b	0.488 a
F val	12.900**	1.698 ns	34.132**	1.050 ns
Cd (ppb)				
No	29.360 a	3.286 a	3.940 a	3.653 a
Middle	102.106 b	5.400 a	5.493 a	5.353 a
Dense	123.340 c	6.793 a	4.780 a	6.593 a
F val	177.283***	2.402 ns	0.370 ns	4.291 ns
Cr (ppb)				
No	18.640 a	19.326 a	17.246 a	30.246 a
Middle	22.246 b	17.453 a	60.553 c	28.400 a
Dense	31.566 c	26.920 b	43.113 b	28.140 a
F val	71.333***	42.861***	635.229***	0.942 ns
Ni (ppb)				
No	8.366 a	2.506 a	4.000 a	1.766 a
Middle	10.180 b	5.326 b	6.020 b	4.826 b
Dense	17.600 c	16.213 c	6.400 c	5.860 b
F val	107.306***	354.737***	23.417**	20.270**
Fe (ppm)				
No	4.593 a	13.546 a	9.146 a	10.300 a
Middle	7.860 b	13.293 a	40.573 b	28.926 c
Dense	13.033 c	18.780 b	54.353 c	19.266 b
F val	617.744***	38.081***	16,847.105***	2679.566***
Mn (ppm)				
No	4.213 a	3.113 a	2.506 a	7.360 b
Middle	5.126 b	3.533 b	6.573 b	6.340 a
Dense	4.800 b	5.606 c	7.593 c	7.233 b

Table 3 (continued)

	Salix babylonica	*Robinia pseudoacacia*	*Sophora japonica*	*Aesculus hippocastanum*
F val	9.167*	150.166***	1494.920***	39.891***
Zn (ppm)				
No	5.913 a	2.733 a	1.546 a	1.080 a
Middle	17.066 b	5.453 b	4.880 b	1.140 a
Dense	19.273 c	7.660 c	9.086 c	2.400 b
F val	2414.402***	25.860**	682.479***	735.353***

The letters a, b, c, etc. means according to Duncan's test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

ns not significant

*Significant at 0.05 level

**Significant at 0.01 level

***Significant at 0.001 level

not significant in other species. When the values obtained in high traffic density areas are investigated, we see that the highest Cd, Ni, and Zn values were obtained in *S. babylonica,* and highest Cu, Mg, Cr, Fe, and Mn were obtained in *S. japonica.* In areas with high traffic density, only the highest value of Pb was found in *A. hippocastanum,* and the highest value of Ca was found in *R. pseudoacacia*. When these values are investigated, it is seen that the Cu value obtained in *S. japonica* and the Cd value obtained in *S. babylonica* are much higher than the values obtained in other species.

4 Discussion

The results of this study show that heavy metal accumulation significantly changed both at the species level and with respect to traffic density. This result is consistent with many studies conducted on this subject (Ozturk and Bozdogan 2015; Turkyilmaz et al. 2018a, b). Based on our findings, it has been determined that some species accumulate heavy metals at higher levels than others. In areas with high traffic density, the highest values of Pb were obtained in *A. hippocastanum,* highest values of Ca were obtained in *R. pseudoacacia,* whereas the highest values of Cd, Ni, and Zn were obtained in *S. babylonica,* and highest values of Cu, Mg, Cr, Fe, and Mn were obtained in *S. japonica.* In other studies conducted on this subject, *A. hippocastanum* was used as a biomonitor of Pb for air pollution caused by traffic (Tomasevic and Anicic 2010; Anicic et al. 2011), *R. pseudoacacia* was used for Fe, Zn, Pb, Cu, Mn, and Cd (Celik et al. 2005), *S. japonica* was used for Zn, Cd, Hg, Pb, and Cr (Li et al. 2007), and *S. babylonica* was used for Fe, Mn, Zn, Cu, and Cd (Sawidis et al. 2001).

This study reveals that the studied species are variably effective in accumulating different heavy metals, meaning each species has a higher potential of accumulating different heavy metals. Similar results have been obtained in many previous studies (Li et al. 2014; Srivastava et al. 2015; Petrova et al. 2014; Anicic et al. 2011). In addition, various parts of the plants have been used as biomonitors within the studies. In addition to the leaves of higher plants (Turkyilmaz et al. 2018a; Monaci et al. 2000; Anicic et al. 2011), body shells

(Sawidis et al. 2001) and trunks (Gao et al. 2015) are also used as biomonitors. But the most commonly used organelles are leaves (Shahid et al. 2017; Turkyilmaz et al. 2018a, b).

The recent previous study in Turkey which is Turkyilmaz et al. (2018b) worked on the species of *Tilia tomentosa, Elaeagnus angustifolia, Prunus cerasifera,* and *Ailanthus altissima* for heavy metals on traffic density. The results of studies represented that the quantity of Pb (17.106 ppb) measured in *Tilia tomentosa* grown in regions with less dense traffic is even greater than the quantity of Pb measured in other species growing in regions with intensive traffic. The same applies to the quantity of Cd in *Tilia tomentosa* and the quantity of Cu and Ni in *Prunus cerasifera.* Another noteworthy fact is that there is a large quantity of Cu accumulation compared to other plant species in *Prunus cerasifera*. The quantity of Cu measured in *Prunus cerasifera* was 148.253 ppb in regions without traffic and 127.593 ppb in areas with heavy traffic (Turkyilmaz et al. 2018b). Among other plant species, *Ailanthus altissima* is the species with the highest Cu (102.660 ppb) in the heavy traffic areas. The same is true for Ni accumulation.

In this study, the variation of heavy metal accumulation in leaves was determined in different species. As a result of the study, it was determined that heavy metal accumulation changed significantly between species. Studies have shown that heavy metal accumulation in plants varies depending on many factors such as the plant species (Ozturk and Bozdogan 2015), different organelles of the same plant (Tošić et al. 2016; Yabanli et al. 2014), climatic conditions (Březinová and Vymazal 2015; Guney et al. 2017), air pollution, and traffic density (Turkyilmaz et al. 2018b).

Studies have shown that the heavy metal accumulation process in plants is closely related to plant anatomical structure. At this stage, the size and structure of the stomata play a particularly active role. In plant leaves, stomata control the entry of CO_2 and water vapor, and they are the organelle with the highest potential to detect heavy metal accumulation in leaves (Xiong et al. 2014; Xu and Zhou 2008). The size and density of stomata are significantly affected by environmental conditions (Cetin et al. 2017a; Galmés et al. 2007; Pearce et al. 2006). Especially in the morning (07:00–10:00 am), the concentration of heavy metals (Pb, Cd, Fe, etc.) increases with the exhaust gases released at times of peak traffic. At the same time, the amount of moisture in the air reaches its highest value with the effect of the terrestrial climate. As a result of the combination of these two effects, heavy metals adhere to the surface of leaves, and the concentration of heavy metals increases in the leaves.

In various studies, it has been stated that stomata structure and density can be affected by many environmental factors (Banon et al. 2004; Beerling et al. 1997) such as the drought stress of the plant (Yang and Wang 2001; Zhang et al. 2006; Liu et al. 2006), light (Sevik et al. 2016), and salt stress (Zhao et al. 2001; Romero-Aranda et al. 2001). In fact, studies have shown that air pollution is also one of the important factors affecting the structure and density of stomata (Cetin et al. 2017a).

Heavy metal accumulation of plants is most probably related to their anatomical and physiological structures. Anatomical and morphological characteristics of plants are formed as a result of mutual interaction of genetic and environmental conditions (Sevik et al. 2012; Trujillo-González et al. 2016; Delgado-García et al. 2013; Trujillo-González et al. 2011; Liang et al. 2016, 2017). Therefore, as significant differences can be found between species (Sevik et al. 2017a), there are also large differences in the anatomical and morphological structure between different subspecies, varieties, forms, and even origins within the same species (Cetin et al. 2017b), and these differences also cause the plant to react differently to external factors (Sevik et al. 2017b). This is related to the genetic structure of the plant. It is extremely probable that a similar situation exists for the capacity of heavy metal accumulation. Therefore, it is possible to say that in addition to the species, the genetic structure and age of the plant will also be effective on the accumulation of heavy metals. As a matter of fact, Shahid et al. (2017) indicate that young leaves accumulate more metal than older leaves because the upper leaf epithelia of young leaves are thinner.

Since anatomical and morphological characteristics of plants are shaped as a result of the mutual interaction of genetic and environmental conditions, environmental factors are one of the most important factors affecting plant structure (Sevik et al. 2012; Yigit et al. 2016a). Environmental factors, that is, growth conditions, have been implicated in a variety of studies in which they significantly influence the response of plants to stress factors (Yigit et al. 2016b). It has been determined that environmental conditions also cause significant changes in plant anatomical and physiological structure. For example, Sevik et al. (2013) state that there may be 2–3-fold differences in the amount of chlorophyll between leaves growing in the shade and leaves growing under intense light. Similar results have also been presented for other factors (Zeren et al. 2017; Cetin 2016, 2017).

Reducing environmental pollution is one of the most important agenda items today, where improving the quality of urban life has become crucial. Especially in urban centers where traffic density and human activities are high, air pollution can be many times higher than in rural areas (Sevik et al. 2016). Increasing the amount of open and green spaces is recommended as the most effective way to reduce the effects of air pollution. This is because green plants play an important role in reducing air pollution (Sevik et al. 2017a, b). Therefore, the concentration of heavy metals in the air can also vary depending on many parameters. Studies on this subject are of great importance in order to monitor this change and to be able to use plants effectively to reduce heavy metal concentrations. It is particularly important that comparisons should be made by using different plant species in these studies, therefore determining which plants can be used against different pollution factors.

5 Conclusion

In this study, highest Cd, Ni, and Zn values were obtained in *S. babylonica*, and highest Cu, Mg, Cr, Fe, and Mn values were obtained in *S. japonica* in areas with high traffic density, whereas the highest Pb value was obtained in *A. hippocastanum*. Therefore, it is beneficial to use species determined as the biomonitor of these metals.

Results of this study reveal that Cu values obtained in *S. japonica* and Cd values obtained in *S. babylonica* are significantly higher than other species. Using *S. japonica* and *S. babylonica* for these two elements can help achieve more effective results in terms of reducing heavy metal concentration in the air.

Today, air pollution in urban centers has become one of the most important problems of cities. Therefore, disseminating and diversifying similar studies is important for determining the most effective plant species in the removal of heavy metals in the air. In future studies, topics such as accumulation of different heavy metals on different organelles of the plant, and which plants accumulate the highest quantities of metals depending on different weather conditions should also be studied in addition to different plant species.

Author contributions All authors contributed equally in the preparation of this manuscript.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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