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RESEARCH ARTICLE

Determination of Pb and Mg accumulation in some of the landscape plants in shrub forms

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Abstract

Heavy metals have a separate precaution in the air pollution components as they are not easily deteriorated in nature, they tend to bioaccumulate, they are carcinogenic or poisonous, and they can be toxic even at low concentrations. Therefore, monitoring of heavy metal pollution is of great importance. Plants are frequently used as biomonitors to monitor the heavy metal pollution. However, the heavy metal accumulation capacities of plants can vary considerably depending on the plant species, as well as on the organelle basis and the amount of particulate matter in the environment. It is also very important to determine how much of the heavy metal concentrations found in plants are derived from the plant species and how much from the particulate matter on the organ. In this study, it was aimed to determine the change of heavy metal accumulation in some landscape plants grown in the city center of Kastamonu depending on plant type, plant organism, washing status, and traffic density. For this purpose, leaf and branch samples were collected from individuals of *Ligustrum vulgare* L., *Euonymus japonica* Thunb., *Biota orientalis* L., *Juniperus sabina* L., *Berberis thunbergii* DC, *Mahonia aquifolium* (Pursh) Nutt., and *Buxus sempervirens* L., which are frequently used in urban landscape designs growing in areas with heavy, low dense, and no traffic. Some of the collected samples were washed, and heavy metal analyses were conducted to determine the amount of Pb and Mg concentrations. It was remarkable that Pb concentration was higher in branches than in the leaves for all the species. And the alteration depending on traffic density on the base of the factors studied was in different proportion depending on the metals.

Keywords Heavy metal · Landscape · Plant · Pollution · Shrub

Introduction

The Earth's atmosphere is mainly composed of oxygen (O_2), nitrogen (N_2), and carbon dioxide (CO_2). However, the rapid economic development, urbanization, and industrialization processes that have taken place in the last 30 to 40 years has significantly disturbed the composition and quality of the atmosphere by spreading various pollutants. The most common organic and inorganic atmospheric pollutants include ozone (O_3), sulfur dioxide (SO_2), nitrogen oxides (NO_x), CO_2, hydrogen fluoride, carbon monoxide (CO), and formaldehyde (HCHO) (Cruz et al. 2015; Mossi 2018; Cetin 2019; Cetin et al. 2019a, 2019b).

Heavy metals have a separate importance among air pollution factors. Because heavy metals do not spoil in nature and do not disappear easily. They also tend to bioaccumulate. Therefore, the determination of the heavy metal concentration has a great importance in terms of

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determining the risk areas and risk level of air pollution (El-Hasan et al. 2002, Turkyilmaz et al. 2018a, 2018b; Aricak et al. 2019a, 2019b; Bozdogan Sert et al. 2019).

The pollution of the atmosphere by heavy metals is mainly due to stationary or mobile sources such as incineration, petroleum combustion in homes, power plants, industrial units, vehicle traffic, and re-dusting of contaminants (Manno et al. 2006; Turkyilmaz et al. 2018c, 2018d; Cetin 2019; Cetin et al. 2019a, 2019b; Bozdogan Sert et al. 2019). Among these, the most important activities that are sources of atmospheric pollution are heavy metal emissions from industrial and traffic (Martley et al. 2004; Uzu et al. 2011). Heavy metals such as As, Cr, Pb, Ni, (Zn), Cd, and V are mostly released from industrial sources and are carcinogenic (Shahid 2015). As, Cd, Pb, Cr, and Hg are among the most toxic heavy metals, especially for toxicity potential and exposure of living organism (Shahid et al. 2017).

As well as majority of them are carcinogenic or toxic, heavy metals also have a separate importance among the air pollution components due to their tendency to bioaccumulate, that they do not decompose easily in nature (Shahid et al. 2017; Turkyilmaz et al. 2019; Sevik et al. 2019a). Therefore, it is of great importance to determine the methods of heavy metal pollution and the removal of heavy metals from the atmosphere.

Plants are frequently used as biomonitors to monitor the heavy metal concentration. Many species can be used as biomonitors of traffic-sourced air pollution (Petrova et al. 2014; Ozel et al. 2015; Sevik et al. 2019b, 2019c). Determination of which species are most suitable for monitoring heavy metal pollution is also of great importance for these species to be used effectively in the removal of such heavy metals from the air. In this study, it was aimed to determine the variation of Pb and Mg accumulation depending on plant species, plant organ, washing status, and traffic density in some landscape plants grown in the city center of Kastamonu.

Material and methods

Collection of the samples

The leaf samples that were collected from the center of Kastamonu city where located at 41° 22′ 35.85″ N and 33° 46′ 35.38″ E with north of Turkey were used within the study. The city center of Kastamonu is generally built in a valley, and the traffic is quite crowded in the city center as it is on many cities. The areas with heavy traffic where the samples are collected within the study are located in the city center of Kastamonu, which has a 4-lane highway with 2 lanes on each side and has the highest traffic density in the city.

The areas with low dense traffic that were chosen as cases for the study are on the main road, but the traffic is quiet fluent on these areas. Within the scope of the study, the samples were collected from the routes of Taşköprü and İnebolu exists of city center. There is a two-lane road in this area, but the traffic is quiet fluent, and the traffic density is very low compared with the city center. At the areas with no traffic, the areas where there is no entrances for any kind of vehicles within 50 m were chosen. These areas are located in Kuzeykent region, and majority of the areas are located in the campus of Kastamonu University.

Leaf samples were collected from the species of *Ligustrum vulgare* L. (Lv), *Euonymus japonica* Thunb. (Ej), *Biota orientalis* L. (Bo), *Juniperus sabina* L. (Js), *Berberis thunbergii* DC (Bt), *Mahonia aquifolium* (Pursh) Nutt. (Ma), and *Buxus sempervirens* L. (Bs), which are frequently used in landscape designs. Leaf samples were collected at the end of the vegetation season and bagged, labeled, and brought to the laboratory.

Pre-processing

The samples, which were classified and labeled in the laboratory, were stored and air-dried for 15 days. The air-dried samples were then dried in drying oven at 45 °C for a week. Experiments were started for heavy metal analysis in dried samples on the same day.

Determination of the heavy metals

Plant samples were pulverized and were weighed as 0.5 g and put into tubes designed for microwave. A total of 10 mL of 65% HNO3 was added to the samples. During this process, the fume cupboard was used. The prepared specimens were then burnt at 280 Psi pressure in a microwave device and at 180 °C for 20 min. The tubes were removed from the microwave after being processed and left to cool. Deionized water was added to the cooled samples, and tubes were filled until 50 mL was completed. Prepared samples were filtered through filter paper and then were read on the ICP-OES instrument at the appropriate wavelength.

Statistical analyses

The obtained data were evaluated with the help of SPSS package program; variance analysis was applied to the data and homogeneous groups were obtained by applying the Duncan test to the values having at least 95% confidence level differences statistically. The obtained data is simplified and tabulated and interpreted.

Results

The variation of Pb concentration

Within the scope of study, the change of Pb concentration due to plant species, organ, and washing was determined in areas with no, low dense, and heavy traffic, and mean values, *F* value, and significance level obtained by variance analysis and homogeneous groups resulting from the Duncan test are shown in Table 1.

As it is seen on the table, the variation of Pb concentration in areas with no, low dense, and heavy traffic varies statistically meaningful at 99.9% confidence level. Data obtained from the areas with no traffic formed 14 homogeneous groups according to the results of the Duncan test. While the lowest values of Pb concentration were calculated in unwashed Bo leaves (78 ppb), washed Mh branches (182 ppb), and washed Js branches (312 ppb), the highest values were calculated in unwashed branches of Lv (2791 ppb), Bs (2666 ppb), and Bt (2663 ppb).

The data formed 12 homogenous groups according to the results of the Duncan test. The lowest values of Pb concentration were calculated in in washed Bo leaves (270.9 ppb), unwashed Bs leaves (354.3 ppb), unwashed Js leaves (299), unwashed Mh leaves (417 ppb), and unwashed Bo leaves (452 ppb). The highest values were obtained from unwashed Bs branches (11,934 ppb), washed Lv branches (5077), and washed Js branches (4497 ppb).

It is thought that the most valuable data in terms of Pb concentration in the study were the data obtained from the

Table 1 Differences in Pb concentrations depending on species and organelle in correlation with traffic density

Species	Organ	Washing	Traffic density			*F* value
			No	Low dense	Heavy	
Lv	Leaf	Washed	745 Bdefgh	594 Aab	971 Cabcd	56,881***
		Unwashed	980 Ahi	659 Aabc	3153 Bi	149,539***
	Branch	Washed	522 Abcdef	5077 Bk	577 Aab	4033,284***
		Unwashed	2791 n	2969 efgh	3139 i	0,765 ns
Ej	Leaf	Washed	948 ghi	1229 c	2090 fg	1211 ns
		Unwashed	984 Ahi	1093 Abc	1792 Bef	124,289***
	Branch	Washed	1181 Bij	3324 Cfghi	503 Aa	248,093***
		Unwashed	1080 Ahij	3123 Befgh	3394 Bij	139,507***
Bo	Leaf	Washed	826 Cfgh	452 Ba	333 Aa	75,958***
		Unwashed	78 Aa	3317 Cfghi	936 Babcd	360,926***
	Branch	Washed	2214 Bkl	3530 Chi	606 Aab	95,860***
		Unwashed	1373 Aj	2643 Bde	3761 Cj	44,109***
Js	Leaf	Washed	609 Bcdefg	299 Aa	1412 Ccde	322,511***
		Unwashed	792 Aefgh	826 Aabc	1513 Bdef	169,589***
	Branch	Washed	312 Aabc	4497 Cj	876 Babcd	1093,234***
		Unwashed	456 Abcde	3737 Ci	3025 Bhi	245,142***
Bt	Leaf	Washed	1254 ij	1215 c	1288 cde	1686 ns
		Unwashed	560 Acdef	3166 Cefghi	1331 Bcde	1031,730***
	Branch	Washed	2423 Blm	2835 Bdef	623 Aab	7244*
		Unwashed	2663 mn	2318 d	2531 gh	1074 ns
Mh	Leaf	Washed	789 Befgh	417 Aa	636 Bab	12,197**
		Unwashed	777 Adefgh	803 Aabc	1174 Bbcde	53,521***
	Branch	Washed	182 Aab	2886 Cdefg	478 Ba	201,828***
		Unwashed	422 Abcd	2640 Bde	3521 Cij	94,427***
Bs	Leaf	Washed	807 Befgh	645 Aabc	861 Cabc	80,570***
		Unwashed	738 Bdefgh	712 Aabc	1608 Cef	451,249***
	Branch	Washed	2044 Bk	3456 Cghi	488 Aa	86,117***
		Unwashed	2666 Amn	11,934 Cl	2912 Bhi	826,603***
F value			51,463***	161,500***	32,046***	

******significant at 0.05 level; significant at 0.01 level; significant at 0.001 level; *ns* not significant. The letters a, b, c, etc. mean according to the Duncan test results and 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 areas with heavy traffic. The data obtained in areas with heavy traffic formed 10 homogenous groups. The lowest Pb concentration amounts were calculated in washed Bo leaves (333 ppb), washed Mh branches (478 ppb), and washed Bs branches (488 ppb) in areas with heavy traffic. The highest values of Pb concentration were calculated in unwashed branches of Bo (3761 ppb), Mh (3521 ppb), and Ej (3394 ppb) species in areas with heavy traffic. It is remarkable that the lowest values of Pb concentration were calculated in washed samples, and the highest values were calculated in unwashed samples in areas with heavy traffic.

When the variation of Pb concentration due to traffic density is examined, it is seen that the difference between the samples of unwashed Lv branches, washed Ej leaves, washed Bt leaves, and unwashed Bt branches is not statistically significant at least at 95% confidence level depending on traffic density. It was determined that the variation of Pb concentration in all samples other than these was statistically significant at 99.9% confidence level.

When the Duncan test results are examined, it is seen that all factors affect Pb concentration. It is seen that the amount of Pb concentration differs significantly depending on traffic density among the samples of washed and unwashed leaves and branches. When also considering the samples that did not show statistically significant difference, it is seen that more than 70% of the values of Pb concentration in areas with no traffic is in first homogenous groups. The variation of Pb concentration is seen more clearly on unwashed samples. The highest values of Pb concentration was calculated in 10 of 14 unwashed samples in areas with heavy traffic.

Apart from this, there are also significant differences between the values of Pb concentration depending on organs. When the values are examined, it is seen that the amount of Pb concentration is two times more in branches than the amount in the leaves. It is also noteworthy that generally, the highest values of Pb concentration in branch samples were of those which were collected from the areas with low dense traffic.

The variation of Mg concentration

Within the scope of study, the change of Mg concentration due to plant species, organ, and washing was determined in areas with no, low dense, and heavy traffic, and mean values, F value, and significance level obtained by variance analysis and homogeneous groups resulting from the Duncan test are shown in Table 2.

When the data on the table is examined, it is seen that the variation of Mg concentration in areas with no, low dense, and heavy traffic varies statistically meaningful at 99.9% confidence level. Data obtained from the areas with no traffic formed 11 homogeneous groups according to the results of Duncan test. The lowest values were obtained from the washed branches of Bo (1303 ppm), Js (2086 ppm), and Bs (2316 ppm) species. The highest values of Mg concentrations in areas with no traffic were calculated in unwashed branches of Lv (6196 ppm), Mh (5024 ppm), and Bs (5004 ppm) species.

The data obtained from the areas with low dense traffic formed 17 homogeneous groups according to the results of the Duncan test. The lowest values of Mg concentration were obtained from the unwashed samples. While the lowest values of Mg concentrations were calculated in unwashed samples of Bo branches (1773 ppm), Bo leaves (1936 ppm), and Bs branches (2098 ppm), the highest values were calculated in washed branches of Mh (10,115 ppm), Ej (10,099 ppm), and Lv (10,072 ppm) species.

Data obtained from the areas with heavy traffic gathered in 12 homogenous groups according to the results of the Duncan test. While the lowest values of Mg concentration in areas with heavy traffic were calculated in unwashed Js branches (2089 ppm), washed Bs branches (2460 ppm), and unwashed Bs branches (2798 ppm), the highest values were obtained from the unwashed samples. The highest Mg concentration values were calculated in unwashed samples of Lv branches (9995 ppm), Lv leaves (9977 ppm), and Bo branches (7443 ppm).

According to the variance analysis results of the Mg concentration on the basis of samples depending on the traffic density, the variation of the Mg concentration in all the study samples is statistically significant at 99.9% confidence level. According to the Duncan test results, it is seen that most of the data obtained in areas with no traffic, generally is in the first homogeneous group, and most of the data obtained in areas with heavy traffic is in the last homogeneous group. This indicates that the amount of Mg concentration in samples has varied greatly depending on traffic density. There is no significant difference in the organ and washing condition factors that was studied due to the traffic density.

Results and discussion

Discussion of variation of Pb concentration

The Pb concentration is of particular importance in heavy metals. Pb, an element widely used in industrial and agricultural activities, is therefore a very common heavy metal, which radiates to the atmosphere as metal or composite and is toxic in all cases. Pb is the heavy metal that most damages the ecological system with human activities (Mossi 2018). Therefore, a large number of studies have been carried out on the variation of Pb depending on traffic density (Assirey et al. 2015; Galal and Shehata 2015; Akarsu 2019).

As a result of the study, the lowest values of Pb concentration was calculated in washed; the highest values were

Table 2 Differences in Mg concentrations depending on species and organelle in correlation with traffic density

Species	Organ	Washing	Traffic density			*F* value
			No	Low dense	Heavy	
Lv	Leaf	Washed	4987 Ai	4997 Bij	5001 Chi	1271,845***
		Unwashed	4996 Ai	4998 Bij	9977 Cl	957,778***
	Branch	Washed	2547 Ae	10,072 Cp	4959 Bg	157,484,685***
		Unwashed	6196 Ak	9965 Bo	9995 Bl	26,945,055***
Ej	Leaf	Washed	4988 Bi	4986 Ai	4999 Chi	1943,925***
		Unwashed	4986 Ai	4986 Ai	4999 Bhi	1220,216***
	Branch	Washed	4985 Bi	10,099 Cpr	4985 Agh	5,982,288,381***
		Unwashed	4988 Ai	7885 Cn	5052 Bj	233,901,009***
Bo	Leaf	Washed	4984 Bi	4968 Ai	4987 Cgh	1680,288***
		Unwashed	2513 Bd	1936 Ab	4988 Cgh	32,887,676***
	Branch	Washed	1303 Aa	3852 Bf	4385 Cd	7735,216***
		Unwashed	4976 Bi	1773 Aa	7443 Ck	100,191,783***
Js	Leaf	Washed	4989 Bi	5027 Cj	4988 Agh	13,113,343***
		Unwashed	4987 Bi	4859 Ah	4984 Bgh	4880,639***
	Branch	Washed	2086 Ab	5537 Ck	4539 Be	15,019,264***
		Unwashed	4987 Bi	5944 Cl	2089 Aa	57,890,087***
Bt	Leaf	Washed	4987 Ai	4996 Bij	5000 Chi	1710,536***
		Unwashed	4986 Bi	4984 Ai	4999 Chi	5293,400***
	Branch	Washed	4719 Bg	2980 Ae	4986 Cgh	14,447,301***
		Unwashed	4679 Bf	2631 Ad	4655 Bf	7956,985***
Mh	Leaf	Washed	4988 Ai	4988 Ai	5030 Bij	35,882***
		Unwashed	4990 Ci	4988 Bi	4987 Agh	55,081***
	Branch	Washed	4799 Ah	10,115 Cr	5011 Bhi	257,982,014***
		Unwashed	5024 Bj	6531 Cm	4998 Ahi	940,587***
Bs	Leaf	Washed	4987 Ai	4988 Bi	4992 Ch	218,087***
		Unwashed	4992 Ci	4987 Ai	4988 Bgh	156,760***
	Branch	Washed	2316 Ac	4697 Cg	2460 Bb	2373,893***
		Unwashed	5004 Cij	2098 Ac	2793 Bc	70,091,293***
F value			16,738,026***	38,210,359***	29,559,383***	

******significant at 0.05 level; significant at 0.01 level; significant at 0.001 level; *ns* not significant. The letters a, b, c, etc. mean according to the Duncan test results and 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

calculated in unwashed samples in areas with heavy traffic. In general, the values of Pb concentration obtained in branches are two times more than the values obtained in leaves. It is noteworthy that, unlike other metals, there is no difference between species in terms of Pb concentration.

As well as being an important metal for humankind for many years, Pb is on the first order among the metals that cause environmental pollution (Mossi 2018). When the concentration of Pb exceeds 300 ppm, it is potentially hazardous for human health (Asri and ve Sönmez 2006).

More than normal levels of lead can be found in plant and animal nourishment especially in the areas close to the city centers or industrial areas (França et al. 2017; Shahid et al. 2017). In addition, lead-containing gasoline is also an important source (Mossi 2018). Therefore, there are numerous studies that proves the relationship between Pb and traffic density (Qing et al. 2015; Begum et al. 2017).

Many studies have been conducted on the usage of several plant species as biomonitor of Pb. Some of the studies exploring the variation of Pb concentration dependin on the traffic density, and the species that were studied are *Elaeagnus angustifolia* L. (Aksoy and Sahin 1999), *Cupressus sempervirens* L. (Çavuşoğlu et al. 2005), and *Cedrus libani* A.Rich. (Demirayak et al. 2011), *Magnolia grandiflora* L. and *Acacia cyanophylla* Lindl. (Tanushree et al. 2011), *Alstonia scholaris* (L.).R. Br., *Ficus bengalensis* L., *Morus alba* L., and *Polyalthia longifolia* Sonn. (Sawidis et al. 2011), *Platanus orientalis* L., and *Pinus nigra* J.F. Arnold, *Sophora japonica* L (Li et al. 2007).

Discussion of variation of Mg concentration

Mg is a very light white mineral that can be burned with a very bright light in the air, which can exist as various compounds in the soil. The largest amount of Mg in the Earth's crust is in the sea. Magnesium is one of perhaps the most important of the 11 essential minerals, along with calcium, phosphorus, sodium, potassium, iron, zinc, copper, chromium, iodine, and selenium. Magnesium, exists as about 20–28 g in our body, of which 60% in bones and teeth and 49% in muscles. Compared with the past years, people are taking this mineral less than before. Mg is a vital mineral and is very difficult to absorb from the intestines. The daily requirement is up to 300 mg, which can cause stool softening if taken in excess. During pregnancy and breastfeeding, Mg need increases. Magnesium is required wherever energy is needed in the body. Lack of Mg in our body may cause constipation, cramps, and contractions in the muscles. Since the body cannot produce this mineral on its own, magnesium must be taken through food. In plants it exists in chlorophyll and retain energy photons from the sun (Işık et al. 2004; Boğa 2007).

The magnesium in the soil is used by plants and can be described as the iron of the plant world. Similar to the iron-hemoglobin relationship in humans, magnesium enters the chlorophyll structure in plants. The use of potassium and phosphorus animal fertilizers on plants consumes magnesium, which changes the magnesium intake ability of plants (Işık et al. 2004). As a result of the study, it was determined that the Mg concentration varied from 4009 to 6557.5 ppm depending on the plant species. It was determined that the Mg concentration in the analyses performed did not vary depending on the organs and washing, but increased depending on traffic density. Mg is also the subject of studies on heavy metals (Çavuşoğlu et al. 2016; Turkyilmaz et al. 2018b). However, Mg is more commonly regarded as a plant nutrient (Saltan and Canbay 2015).

General evaluation

As a result of this study, it was determined that one of the most important factors determining the accumulation of heavy metals is plant species. As a matter of fact, it has been determined that there are great differences among species in some elements. It is noteworthy that especially Pb, the element with toxic effect even at low doses, showed almost two times more amounts of concentration difference between species (Shahid et al. 2017), and this difference reached up to 2.75 times higher in carcinogenic heavy metals such as Ni and Cr (Shahid et al. 2017), and even this difference was 5 times more in poisonous elements like Cu (Okcu et al. 2009).

There are a number of studies that have been carried out to date to determine that different heavy metals are held in different amounts by different plants (Turkyilmaz et al. 2018a, 2018b). It is stated that the heavy metal accumulation potentials of the plants are closely related to the plant anatomic structure (Turkyilmaz et al. 2018a, 2018b). Heavy metal intake from leaves is a major source of toxic chemicals and physico-chemical properties of metals, morphology, and surface area of plant leaves, chemical, and physical forms of adhered metal, surface texture of leaves (mature and rough), habitus of plant (deciduous or evergreen) environmental conditions, and gas exchange (Beckett et al. 2000; Shahid et al. 2017).

Among these characteristics, the number and size of stoma in leaves are also important factors affecting heavy metal intake (Xu and Zhou 2008; Xiong et al. 2014). Studies show that the number and size of stomas in leaves varies considerably in plant species (Sevik et al. 2017; Cetin et al. 2018a, 2018b).

One of the most important factors affecting the intake of heavy metals in plants is the habitus of the plant. In the studies done, photosynthesis rate of plants is affected by light, temperature, water, and so on (Sevik et al. 2017). Heavy metal accumulation is also directly related to the air entering the stomata and to the amount of heavy metal taken into the leaf. One of the most important factors affecting the rate of photosynthesis is the amount of chlorophyll. It has also been shown that there is a significant difference between the amounts of chlorophyll in the plants and that this difference can even reach ten times depending on the plant species (Çetin 2016).

Precipitation and adherence of heavy metals on plant leaves vary greatly with heavy metal levels in atmospheric particulate matter (PM) (Shahid et al. 2017). The results of the study showed that the concentration of metals such as Pb and Fe changed depending on washing. It has been found through studies that particulate matter in the air acts as a sink for heavy metals, and that these particulate matter can enter the plant surface through the plant surface in various ways or stay there and that the heavy metal concentrations in the plants are closely related to the amount of particulate matter infected with heavy metals (Shahid et al. 2017; Mossi 2018). In addition, the heavy metal concentration in the plants can vary significantly depending on traffic density (Assirey et al. 2015; Galal and Shehata 2015); the organ (Emamverdian et al. 2015; Dimitrijević et al. 2016; Tošić et al. 2016) and the developmental stage (Mossi 2018).

As a result, the heavy metal concentration in plants, in other words, depends on the interaction of many factors such as heavy metal accumulation potential of plant species, heavy metal concentration in the air, plant organ, and environmental conditions. These factors can also affect other factors at the same time. Climatic conditions, for example, significantly alter metal uptake potential of leaves through direct effects on the physico-chemical characteristics of the plant and leaf surface. Climate conditions also affect the biological and metabolic processes in the plant and ultimately affect the uptake and partitioning of metals by the leaves. During the precipitation on the leaves, instantaneous climatic conditions such as moisture, heat, and light affect the metabolic processes of the plant, and thus affect the penetration process along the leaf surface and the movement within the leaf cavities. Similarly, the environmental conditions under which the plants cultivated and subjected to uptake of heavy metals by the leaves, leaf surface characteristics, plant physiology, plant morphology, villus structure, size, density, and leaf size may change the intake of heavy metals (Speak et al. 2012; Shahid et al. 2017; Cetin 2019; Cetin et al. 2019a, 2019b).

Relative humidity is another important climatic factor that affects the uptake of heavy metals by the leaves. Indeed, relative humidity affects the permeability potential of the plant leaf surface. In addition, the relative humidity significantly affects the physico-chemical response of the plants to adsorbated PM in terms of solubility or redox content. When the relative humidity is high, the permeability of the plant leaf surface may increase potentially. Similarly, when relative humidity is high, precipitated PM and heavy metals remain wet, which facilitates penetration of heavy metals into plant leaves. The reason of this is that when the relative humidity in the phyllosphere is high, the heavy metals remain theoretically dissolved and the penetration time of the leaf is prolonged. Thus, the climate factor affects many factors, from the amount of particulate matter in the air, the behavior of heavy metals, the rate of plant growth to the process of penetration of heavy metals into plants, and so; many factors interact with each other (Bondada et al. 2004; Sevik et al. 2019a, 2019b, 2019c).

The effectiveness of factors mentioned above are proven by the studies done up to this day. Apart from these, there are also factors that can affect the heavy metal concentration. For example, besides the plant species, the subspecies, form, variety, and origins of the plant (Sevik et al. 2017; Yucedag et al. 2019), plant stress level (Sevik and Cetin 2015), and genetic structure (Hrivnák et al. 2017; Yigit et al. 2016) are likely to affect heavy metal absorption and consequently heavy metal concentrations in plants. Moreover, all these factors have an interaction with each other. For example, the amount of light may affect the amount of chlorophyll and growth rate of the plant, and the growth rate of the plant may affect the intake of heavy metals. As a matter of fact, Sevik et al. (2013) indicated that there may be 2–3 times difference in the amount of chlorophyll between leaves growing under shadow conditions and leaves growing under intensive light of same plant species. On the other hand, it is also stated that there is a relationship between plant growth and metal concentration (Speak et al. 2012; Shahid et al. 2017). Therefore, the variation of heavy metal concentration in plants is the result of a complex mechanism due to the interaction of many factors.

Suggestions

In the results of study; it has been determined that heavy metal accumulation varies considerably especially on the basis of plant species, and that each plant accumulates different heavy metals at different levels. Since heavy metals are extremely important in terms of human health, monitoring the level of heavy metal pollution is of great importance. For this purpose, plants are extensively used as biomonitors, and numerous studies are carried out on this field. However, in most of the studies carried out so far, leaves have been used as material. However, it was determined that concentrations of Pb is higher in the branches than in the leaves. This result shows that other organs of plants may contain more heavy metals than leaves. Therefore, studies in this area should be diversified, and studies should be carried out in this field, considering that it is possible to use other plant organs besides leaves as biomonitor and may give even more reliable results.

According to the results of the study, the mean Pb concentration in washed samples was determined as 1358.3 ppb, while this ratio was determined as 2144.9 ppb in unwashed samples. This is an indication that the particulate matter on the organ may contain heavy metals and that particulate matter may cause serious health problems. As a solution, it may be suggested to use especially plants with a canopy structure that holds more dust.

Within the scope of the study, it has been determined that the concentration of heavy metals in plants can vary depending on many factors. However, when the information obtained from the literature studies is evaluated, it is seen that the studies done to determine the relation between plant structure and heavy metal accumulation, especially factors affecting the intake of heavy metals by the plants are very limited. Therefore, such studies should be prioritized.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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