Landscape and Ecological Engineering (2022) 18:75–83
https://doi.org/10.1007/s11355-021-00483-6

ORIGINAL PAPER

The change of Cr and Mn concentrations in selected plants in Samsun city center depending on traffic density

Tugba Karacocuk[1] · Hakan Sevik[2] · Kaan Isinkaralar[2] · Aydın Turkyilmaz[2] · Mehmet Cetin[3]

Received: 20 April 2021 / Revised: 26 July 2021 / Accepted: 25 September 2021 / Published online: 19 October 2021

Abstract

In recent years, air pollution has increased significantly due to anthropogenic factors and has become a global problem. Heavy metals in air pollution components; it is of particular importance because they are not easily degraded and disappeared in nature, bioaccumulation in living bodies, some of them can be toxic, toxic or carcinogenic even at low concentrations and even those necessary for living bodies can be harmful at high concentrations. Therefore, monitoring the concentrations of heavy metals in the air is of great importance for human and environmental health. Biomonitoring is the most suitable method for monitoring the concentration of heavy metals. Plants that can accumulate heavy metals in different organs are suitable biomonitors. However, the most appropriate type and organ for monitoring each heavy metal must be determined separately. In this study, the changes in the concentrations of the elements Cr and Mn in *Robinia pseudoacacia, Platanus orientalis, Acer negundo, Ulmus minor* and *Nerium oleander* species were determined by the individuals who grow in areas where there is no traffic, less and dense. The Cr and Mn concentrations in the leaves, bark and wood of the species subject to the study were evaluated. Within the scope of the study, the washing process was also applied to the leaves and shells and the effect of the washing process was tried to be determined. As a result of the study, it was determined that the concentrations of each element in different species vary depending on the traffic density and this change can vary greatly on the basis of element and species.

Keywords Air pollution · Biomonitor · Heavy metal · Selected plant · Traffic density

Introduction

In the last century, in addition to the rapid population growth in the world, urbanization has brought many problems. So much so that it is stated that many of the most important problems in the world today, directly, or indirectly, population growth, population density in urban areas or associated problems (Nagdeve 2004; Boamah et al. 2018; Sevik et al. 2018; Kilicoglu et al. 2021). Growth and urbanization have reached such serious proportions that in the 1900s, the total world population was only around 700 million and about 9% of the population lived in urban areas, while in 2020 the world population exceeded 7.8 billion and the population living in urban 2020areas increased to 56%. In 2030, it is estimated that the world population will exceed 8.5 billion and the proportion of population living in urban areas could reach 90% (Ozturk and Isinkaralar 2018a, b; United Nations 2019). With the industrial revolution, people's desires and needs increased by diversification, and the production to meet these requests and needs resulted in the extracting of mineral resources underground and using them as raw materials in the industry (Christmann 2018; Shahid et al. 2017). This process caused pollution of air, water and soil due to the oscillation of various pollutants used as raw materials in the industry (Haiyan and Stuanes 2003; Isinkaralar et al. 2017; Zwolak et al. 2019). While there are many components of air pollution, heavy metals are of special importance among these components due to their impact on other living things

✉ Kaan Isinkaralar
kisinkaralar@kastamonu.edu.tr

[1] Department of Sustainable Agriculture and Natural Plant Resources, Institute of Science, Kastamonu University, Kastamonu, Turkey

[2] Department of Environmental Engineering, Faculty of Engineering and Architecture, Kastamonu University, Kastamonu, Turkey

[3] Department of Landscape Architecture, Faculty of Engineering and Architecture, Kastamonu University, Kastamonu, Turkey

and ecosystems, especially humans (Burnett et al. 1998). This importance of heavy metals is due to their tendency to bioaccumulate, to be toxic, carcinogenic and deadly even at low concentrations in terms of human health, not being easily eliminated from living bodies, not easily deteriorating and disappearing in nature (Khan et al. 2015; Izah et al. 2016). Air pollution can cause various diseases such as heart diseases, respiratory diseases, stroke and cancer. Studies show a significant relationship between air pollution and diseases such as cardiovascular diseases, lung cancer, asthma attack (Petkova et al. 2013; Lee et al. 2014; Fiordelisi et al. 2017). Several studies conducted have also found a link between air pollution and premature deaths in urban centers (Kim et al. 2015; Grzędzicka 2019; Vermeulen et al. 2019; Hvidtfeldt et al. 2019; Elsunousi 2020; Cheung et al. 2020). It is estimated that air pollution causes the death of approximately 1 out of 8 people worldwide, and this rate is increasing in regions where population density and thus air pollution is higher (Krzyzanowski et al. 2014). The World Health Organization reports that approximately 92% of the world's population live in regions with low air quality in 2014 (Solange et al. 2014; Sevik et al. 2018; Elsunousi 2020).

High-rise plants are one of the most widely used biomonitors to monitor heavy metal pollution in the air (Vladimirovna and Ayushievna 2019; Isinkaralar 2020). Especially the leaves of non-evergreen plants are formed during the vegetation season and are exposed to heavy metal pollution during this period and fall off at the end of the vegetation season (Sevik et al. 2019a, b, c). Determining the heavy metal concentration in these leaves can give important information about heavy metal pollution in that area (Nadgórska-Socha et al. 2013). Therefore, numerous studies have been carried out on the determination of heavy metal concentrations in the leaves of deciduous plants (Moćko and Wacławek 2004; Piczak et al. 2003; Saleh 2018). However, the accumulation of heavy metals within the plant varies significantly on the basis of heavy metal type, plant species and plant organ (Sevik et al. 2020a, b, c). Therefore, to monitor each heavy metal, the most suitable plant species and organ must be determined separately. In this study, it is aimed to determine the change of Cr and Mn concentrations, which are among the heavy metals that are extremely critical for health, depending on plant type, organ, washing condition and traffic density in some plants grown in Samsun city center.

Materials and methods

The study was carried out in Samsun province. Within the scope of the study, samples were collected from regions (N-TR) with heavy traffic (H-TR), low density (LH-TR) and almost no traffic (at least 50 m with no vehicle roads). For this purpose, samples were collected from Samsun city center as the region with heavy traffic, 19 Mayıs district as the region with less traffic and from the suburbs of 19 Mayıs district as the area where there is no traffic.

Within the scope of the study, among the types frequently used in landscape works, samples were collected from five plant species: *Robinia pseudoacacia* (RP), *Platanus orientalis* (PO), *Acer negundo* (AN), *Ulmus minor* (UM), *Nerium oleander* (NO). The samples were collected from the last year's offshoot, i.e., the one-year-old part, towards the end of the vegetation season in 2019, in late October and bagged and labeled and brought to the laboratory. Later, they were separated into their organs without using metal tools. Some of the bark and leaves were subjected to washing, after the last rinsing with pure water, all samples were labeled. In the later stages of the study, the organs were coded considering the washing process, and they were labeled as follows: the washed leaf as "WL", unwashed leaf as "UWL", washed bark as "WB", unwashed bark as "UWB" and wood samples as "WD". The labeled samples were kept in room conditions until they became air-dry without being exposed to direct sunlight for two weeks after pre-treatment. Then, they were dried in an oven at 45 °C for 2 weeks. The dried plant samples were ground into powder and weighed 0.5 g and put into tubes designed for microwave. 10 mL 65% HNO_3 was added on the samples. The prepared samples were then burned in a microwave device at 280 PSI pressure and 180 °C for 20 min. After the procedures are completed, the tubes are removed from the microwave and left to cool. They were completed to 50 ml by adding deioned water on the cooling samples. After the prepared samples were filtered through filter paper, they were read in ICP-OES device at appropriate wavelengths. The resulting values were multiplied by the dilution factor and the Cr and Mn concentrations subject to the study were calculated. The obtained data were evaluated with the help of SPSS package program, variance analysis was applied to the data, and the Duncan test was applied to the values with statistically significant differences at the confidence level of at least 95% and homogeneous groups were obtained. The data obtained were simplified and interpreted by tabulating.

Results

The variation of Cr concentration on the basis of species, organ and traffic density is given in Table 1.

It was determined that the changes of Cr concentration on the basis of species and organs were statistically significant (at least $p < 0.01$) in all traffic densities. When the change of Cr concentration in areas where there is no traffic is examined, the lowest values are found in the first groups according to Duncan test, NO-UWB (24.93 ppb),

Table 1 Change of Cr (ppb) concentration on the basis of species, organ and traffic density

Species	Organ	N-TR	LH-TR	H-TR	*F* value	Error
RP	WL	82.06 cB	29.73 aA	24.66 aA	177.759	0.000
	UWL	143.66 fg A	436.00 kC	298.36 hB	6668.616	0.000
	WB	138.63 efgA	209.16 gB	483.43 jkC	741.855	0.000
	UWB	97.6 cdA	269.46 hC	193.66 fB	530.811	0.000
	WD	177.16 hiB	327.23 iC	59.83 bA	105.512	0.000
PO	WL	88.00 cA	146.90 deB	200.66 fC	27.950	0.001
	UWL	198.83 ijB	187.13 efgA	462.40 jC	5676.287	0.000
	WB	471.73 mC	157.00 defA	389.80 iB	150.848	0.000
	UWB	130.23 efA	120.33 cdA	209.66 fB	50.490	0.000
	WD	152.46 fgA	225.46 gA	505.90 kB	25.473	0.001
AN	WL	32.80 abA	67.73 abB	587.20 lC	1315.473	0.000
	UWL	41.46 abA	233.60 ghB	1034.40 mC	686.951	0.000
	WB	252.06 kB	129.46 dA	261.33 gB	140.879	0.000
	UWB	472.26 mC	80.70 bcA	261.60 gB	8132.175	0.000
	OD	98.16 cdA	379.40 jC	150.66 dB	664.839	0.000
UM	WL	34.80 ab	51.86 ab	31.06 a	1.123	0.385
	UWL	116.93 deB	73.06 abA	190.80 fgC	52.789	0.000
	WB	368.53 lB	215.16 gA	212.66 fA	108.843	0.000
	UWB	189.66 iB	187.36 efgB	28.40 aA	1234.602	0.000
	WD	162.66 ghB	187.16 efgB	92.66 cA	30.682	0.001
NO	WL	52.73 bA	194.83 fgC	77.86 bcB	536.130	0.000
	UWL	192.53 iB	132.53 dA	145.20 dA	14.614	0.005
	WB	218.33 jC	188.10 efgB	163.20 dfA	23.706	0.001
	UWB	24.93 aA	420.53 jkC	164.06 dfB	1524.432	0.000
	WD	82.3 cB	53.46 abA	147.93 dC	199.539	0.000
F value		11.659	4.110	4.252		
Error		0.000	0.005	0.004		

Uppercase letters show horizontal direction, whereas lowercase letters indicate vertical directions

AN-WL (32.80 ppb), UM-WL (34.80 ppb) and AN- UWL (41.46 ppb); according to Duncan test results, the highest values were obtained in AN-UWB (472.26 ppb) and PO-WB (471.73 ppb), which form the last homogeneous group. In areas with low traffic, the lowest Cr concentration was obtained in RP-WL (29.73 ppb), and this organ was only in the first homogeneous group. Along with RP-WL, UM-WL (51.86 ppb), NO-WD (53.46 ppb), AN-WL (67.73 ppb) and UM-UWL (73.06 ppb) stand out as values that are in the first homogeneous group. The highest values were obtained in RP-UWL (436.00 ppb), NO-UWB (420.53 ppb) and AN-WD (379.4 ppb) in areas with low traffic.

According to the Duncan test results in areas with high traffic, the values that make up the first homogeneous group were obtained in RP-WL (24.66 ppb), UM-UWB (28.40 ppb) and UM-WL (31.06 ppb). The highest values in these areas were AN-UWL (1034.4 ppb) and AN-WL (587. 21 ppb). It is noteworthy that the highest values were obtained in AN leaves. When the change of Cr concentration in different species and organs depending on the traffic density was examined, it was found that only the change in the WL organ of the UM type was not statistically significant ($p > 0.05$); and it is seen that the change in all other organs is at a statistically significant level (at least $p < 0.01$).

When the homogenous groups formed by Duncan test were examined, it was determined that the values obtained in 11 out of 24 organs, which were determined to have statistically significant difference, were in the first homogeneous group in areas where there was no traffic. 11 of the values obtained in areas with low traffic and 7 of the values obtained in areas with high traffic were included in the first homogeneous groups as a result of the Duncan test. (Although a total of 24 organs were evaluated, the reason for the total of 29 values in the first homogeneous groups is that in some organs two values are in the same group).

It was determined that 3 homogeneous groups were formed as a result of Duncan test in 17 out of 24 organs where the values obtained differed statistically significantly in areas where traffic density was different. As a result of Duncan test, 3 organs in areas with no traffic, 6 organs in areas with low traffic, 7 organs in areas with heavy traffic were in the third homogeneous group. When evaluated in general, according to the homogeneous groups formed as a result of Duncan test, it was determined that the change in Cr concentration increased with increasing traffic density in 6 of 24 organs and decreased with increasing traffic density in 6 of them. The change of Cr concentration in all organs was examined, it was determined that the most suitable organs to be used for monitoring Cr concentration were AN leaves. In addition to the increase in Cr concentration in AN leaves with the traffic density, the Cr concentration in the unwashed leaves is higher than the Cr concentration in the washed leaves at all traffic densities. The change of Mn concentration on the basis of species, organ and traffic density is given in Table 2.

According to the results of variance analysis, the change of Mn concentration on the basis of species and organ is statistically significant (at least $p < 0.05$) in all traffic densities. When the change of Mn concentration on the basis of species and organ in areas where there is no traffic is examined, it is seen that the lowest values are obtained in NO-WL with 1151.26 ppb, RP-WD with 1211.63 ppb and NO-UWB with 1400.53 ppb. In these areas, the highest values were obtained in PO-UWB (47,185.16 ppb), PO-WL (46,010.46 ppb) and PO-UWL (45,294.46 ppb). It is noteworthy that the highest values were obtained in PO leaves and branches.

In areas with low traffic, the lowest Mn concentrations are obtained in UM-UWL (479.06 ppb), PO-UWB (757.26 ppb) and NO-WD (921.93 ppb), while the highest Mn concentrations are obtained in AN-WL (50,262.53 ppb) and PO-WL (32,419.20 ppb). The highest two values were obtained in unwashed leaves. In areas with high traffic, the values that make up the first homogeneous group according to Duncan test results were obtained in PO-WL (289.06 ppb), UM-WD (294.23 ppb) and RP-WD (311.03 ppb). The highest values in these areas were obtained in NO-UWB (74,533.5 ppb), AWL (43,742.06 ppb) and AN-WB (33,903.63 ppb). It is noteworthy that four of the lowest 5 concentrations obtained in areas with heavy traffic were obtained in woods and the highest values were obtained in unwashed leaves and wood.

The change of Mn concentration in different species and organs depending on the traffic density was examined, it was determined that only the change in the WL organ of the UM type was statistically at 99% confidence level

Table 2 Variation of Mn (ppb) concentration on the basis of species, organ and traffic density

Species	Organ	N-TR	LH-TR	H-TR	*F* value	Error
RP	WL	35,572.56 nC	20,952.26 nB	1777.60 dA	20,323.663	0.000
	UWL	31,606.03 lC	13,456.00 kB	9908.40 jA	13,189.437	0.000
	WB	12,099.13 hB	10,083.36 iA	14,643.50 lC	383.336	0.000
	UWB	10,978.00 fgC	7550.13 hB	5283.20 hA	13,187.417	0.000
	WD	1211.63 aB	1275.20 bcC	311.03 aA	3993.166	0.000
PO	WL	46,010.46 rC	32,419.20 sB	289.06 aA	4388.362	0.000
	UWL	45,294.46 pC	2256.43 dA	13,340.26 kB	69,904.959	0.000
	WB	11,526.06 ghB	1318.83 cA	19,570.40 nC	86,639.412	0.000
	UWB	47,185.16 sC	757.26 abA	19,856.36 oB	59,107.737	0.000
	WD	7538.60 eB	1185.80 bcA	19,213.13 mC	8995.474	0.000
AN	WL	2095.06 bA	50,262.53 tC	43,742.06 tB	99,582.993	0.000
	UWL	2732.53 bcA	27,538.93 rB	64,417.86 uC	68,946.025	0.000
	WB	33,003.96 mB	26,737.8 pA	33,903.63 rB	57.701	0.000
	UWB	36,102.73 nB	26,177.76 oA	44,470.50 uC	1622.002	0.000
	WD	16,632.00 iC	3597.06 fA	6679.20 iB	25,952.322	0.000
UM	WL	2862.00 cB	2758.73 eB	1024.53 cA	11.114	0.010
	UWL	5087.86 dC	479.06 aA	4395.06 fB	13,289.111	0.000
	WB	10,362.06 fC	4180.93 gA	4716.13 gB	2718.671	0.000
	UWB	20,900.23 jC	3171.33 efB	1998.80 dA	31,665.753	0.000
	WD	2652.00 bcB	3330.36 fC	294.23 aA	2609.783	0.000
NO	WL	1151.26 aA	12,557.63 jC	3600.66 eB	9009.639	0.000
	UWL	26,354.66 kB	15,028.53 lA	34,280.53 sC	59,976.699	0.000
	WB	41,444.96 oC	1298.03 cA	32,720.00 pB	5293.743	0.000
	UWB	1400.53 aA	17,350.53 mB	74,533.5 wC	770,139.575	0.000
	WD	2329.80 bcC	921.93 abcB	641.53 bA	834.815	0.000
	F value	3.185	2062.07 a	4.252		
	Error	0.018	80.706	0.004		

Uppercase letters show horizontal direction, whereas lowercase letters indicate vertical directions

($p < 0.01$); and it was statistically significant at 99.9% confidence level ($p < 0.001$) in all other organs. When the homogeneous groups formed by the Duncan test were examined, it was determined that the values obtained in the areas where there was no traffic in 4 of the 25 organs subject to the study were in the first homogeneous group. Twelve of the values obtained in areas with low traffic and 9 of the values obtained in areas with high traffic were included in the first homogeneous groups as a result of Duncan test.

It was determined that 3 homogeneous groups were formed in 23 out of 25 organs subject to the study as a result of Duncan test. As a result of Duncan test, 12 organs in areas with no traffic, 4 organs in areas with low traffic and 7 organs in areas with heavy traffic were in the third homogeneous group. When evaluated in general, according to the homogeneous groups formed as a result of Duncan test, it was determined that the change in Mn concentration decreased with increasing traffic density in 6 of 25 organs and increased with traffic density in only 2 of them. It is noteworthy that as the traffic density increases, the Mn concentration in the RP leaves decreases.

Discussion

Within the scope of the study, changes in the concentrations of Cr and Mn elements in individuals of *Robinia pseudoacacia* (RP), *Platanus orientalis* (PO), *Acer negundo* (AN), *Ulmus minor* (UM), *Nerium oleander* (NO) species, in areas with heavy traffic, low density, and almost no traffic was tried to be determined. Within the scope of the study, the concentration of the elements in the leaves, bark and wood of the species subject to the study was evaluated. Within the scope of the study, the washing process was also applied to the leaves and shells and the effect of the washing process was also tried to be determined. Therefore, within the scope of the study, the change of the concentrations of the elements subject to the study was determined depending on the factors of type, traffic density and organ (washing operations were also evaluated within the organ factor).

As a result of the study, it was determined that the concentrations of each element in different species are at different levels, that is, heavy metal concentrations vary significantly on the basis of species. While the change of Mn element, which is one of the elements evaluated within the scope of the study, is statistically significant in all traffic densities, the change in Cr concentration on the basis of type is significant only in areas with heavy traffic. In studies conducted on the accumulation of heavy metals in different plant species, it was determined that the most important factor affecting the accumulation of heavy metals is plant species. Numerous studies have shown that the variation of heavy metal concentrations in plants grown in the same environment varies greatly (Khan et al. 2015; Mossi 2018; Saleh 2018).

The potential for heavy metal accumulation in plants is the result of the growth performance and the metabolic activities that occur in this process. The growth and development of plants is shaped by the mutual interaction of genetic structure and environmental conditions (Sevik 2012; Yigit et al. 2016a, b; Topacoglu et al. 2016). Therefore, the different levels of heavy metal accumulation in plants grown in the same environment can be attributed to the different genetic structure (Turkyilmaz et al. 2018a, b, c). In the studies conducted on the subject, it has been stated that the genetic structures of different species are at different levels as well as different subspecies, varieties forms and even origins of the same species; and therefore, their anatomical, morphological and physiological characteristics change under the influence of genetic structure (Sevik and Cetin 2015; Yigit et al. 2019).

Within the scope of the study, it was determined that element concentrations differ significantly depending on the traffic density, but this difference is also at different levels based on species and organs. On the other hand, the change of Cr concentration, depending on the traffic density, was statistically insignificant level only in UM, and it was at a significant level in other species. According to average values and Duncan test results, Cr concentration was in the first group in areas where there is no traffic in all types of RP, PO, AN and NO as a result of Duncan test; and it was in the last group in the areas with heavy traffic. On the other hand, it was determined that the Mn concentration in AN and NO species increased in proportion to the traffic density, while the Mn concentration decreased as the traffic density increased in other species.

Therefore, the change of heavy metal concentrations in species depending on the traffic density is valid for elements of which concentration in air increases with traffic density. In studies conducted so far, it has been determined that heavy metals such as Cr, Pb, Ni and Co are one of the most important sources and therefore, as the traffic density increases, the concentrations of these elements in the air also increase (Ewen et al. 2009; Shahid et al. 2017; Cetin et al. 2021). As a result of the study, it was determined that the change of most of the elements on the organ basis is at different levels. This change occurs at different levels for each element. In studies conducted so far, it has been stated that heavy metal concentrations in different organs are at different levels and even this difference can be dozens of times (Zhang et al. 2018; Zhao et al. 2020; Turkyilmaz et al. 2020).

Heavy metal concentrations in different organs of plants grown in the same environment vary depending on factors such as plant organ structure, morphology, surface area, surface texture and size (Hmeer 2020). For example, plant leaves can absorb heavy metals in the air during the entrance and exit of air through stomata, and in this case, the stoma structure affects the intake of heavy metals into the leaf body. Similarly, the rough and cracked shell surface can make it easier for heavy metals to hold there. Therefore, the structure and properties of the organ can significantly affect heavy metal uptake (Hardiman and Jacoby 1984; Greeger et al. 1999; Sert et al. 2019).

Another factor that is evaluated together with the organ factor within the scope of the study is washing state. As a result of the study, it was determined that the concentration of many elements changes due to washing, and the concentrations in the organs washed in some elements and in the unwashed organs are higher in some elements. Studies show that this situation is mostly related to whether particulate matter is contaminated with heavy metals or not (Alagić et al. 2015; Aricak et al. 2019).

Heavy metals can adhere to various particulate matter in the atmosphere after separation from their source, so the particulate materials can contain a complex mixture of heavy metals. Therefore, the effect of the washing process on the concentration of heavy metals depends largely on the contamination with heavy metals of the particulate matter removed from the organ surface by washing. If the particulate matter removed from the surface of the organ by washing is contaminated with a heavy metal, that is, if the heavy metal concentration in the particulate matter is higher than that of the organ, the washing process decreases the heavy metal concentration of the organ, otherwise it increases. Therefore, it is normal to have higher heavy metal concentrations in samples that is washed in some organs and that is not washed in some organs and similar results have been obtained in many studies (Sharma et al. 2008; Cetin et al. 2020; Savas et al. 2021).

Within the scope of study, it is very difficult to interpret the results when the change of the traffic density and the plant species and organs, which are the factors subject to the study, are examined mutually. For example, it has been determined that the Mn concentration decreases as the traffic density increases in 6 of the 25 organs belonging to 5 species and increases with the traffic density in 2 of them; the Cr concentration, on the other hand, increases with the increase of the traffic density in 6 organs and decreases with the increase of the traffic density in 6 of them.

The entrance and accumulation of heavy metals into plant structure is shaped by the influence of many factors. As explained above, plant-related factors such as plant species, genetic structure and habitus; plant organ-related factors such as plant organ structure, morphology, surface area, surface texture and size; environmental factors such as rainfall and moisture amount, heavy metal concentration in the soil, heavy metal concentration in the air; heavy metal related factors such as the type of heavy metal, its interaction with the plant, the duration of exposure; and the interaction of many factors such as these play a role in the entry and accumulation of heavy metals into the plant (Bozdogan 2016; Ristorini et al. 2020).

In conclusion, it is known that air pollution is one of the most important problems in the world today and this problem is growing both in indoor and outdoor environments (Shahid et al. 2017; Mossi 2018). As a result of anthropogenic factors, especially industrial activities and urbanization, soil, water and air pollution has reached a level that threatens human and environmental health in some regions (Isinkaralar et al. 2017; Turkyilmaz et al. 2020).

Among the pollution components, air pollution is of greater importance due to its potential effects. Studies show that there is a significant relationship between air pollution and diseases such as lung cancer, cardiovascular diseases, and asthma attacks. Studies also show a link between the increase in air pollution and premature deaths in cities (Behrens et al. 2018; Elsunousi 2020). Therefore, improving air quality is currently one of the most important and priority issues.

One of the most effective methods in reducing air pollution is the use of plants. Plants contribute to the reduction of air pollution by accumulating heavy metals as well as other pollution factors, and also fulfill many economic, ecological and social functions (Nouri et al. 2009; Turkyilmaz et al. 2020). However, since the metabolism and interaction of each plant with the environment are at different levels, it is essential to determine by carrying out detailed studies that which plants accumulate which metals in greater amounts and the factors that affect this accumulation; so that they can be used as a biomonitor in the monitoring of heavy metals, and for more specific purposes such as reducing heavy metals.

Suggestions

Today, it is accepted by everyone that air pollution is one of the most important factors threatening human, living and environmental health on a global scale. One of the most important components of air pollution is heavy metal pollution. However, it can be said that there is not yet a cheap, easy and sustainable method for effectively monitoring heavy metal pollution in the air. The most effective and accepted method for monitoring heavy metal concentrations is the use of biomonitors. However, as shown in the studies conducted so far, the interaction of each plant with different heavy metals, their absorption and accumulation of these heavy metals are at different levels. Therefore, it is necessary to determine the most appropriate species and organ separately to monitor the change of concentration of each heavy metal in air. As a result of this study, it has been determined that *Acer negundo* leaves are the most suitable biomonitor for monitoring the change of Cr concentration, which is one of the most harmful heavy metals for human and environmental health.

Within the scope of the study, it was determined that some species accumulate Cr and Mn heavy metals much more than other types. In this case, it can be said that the plants in question collect the heavy metals in the air and thus reduce the heavy metal pollution in the air. The use of these species in landscaping and afforestation works in areas with heavy metal pollution may contribute to reducing heavy metal pollution. For this purpose, it is recommended to use *Acer negundo* and *Platanus orientalis* species to reduce both heavy metal pollution.

Acknowledgements This study is produced from the MSc thesis titled as “Changes in Heavy Metal Concentratıons Depending on Traffıc Densıty in Some Plants Grown in Samsun City Center” conducted at Kastamonu University, Graduate School of Science and Engineering, Sustainable Agriculture and Natural Plant Resources Department.

Author contributions TK: raw material collection, processing analysis, interpretation. HS: thesis supervisor, processing analysis, interpretation. KI: conceptualization, software, writing original draft, data curation, and formal analysis. AT: formal analysis, visualization, and review and editing. MC: review and editing. All authors read and approved the final manuscript.

Funding There is no financial support and commercial support.

Availability of data and materials Not applicable.

Declarations

Conflict of interest The authors declare that they no conflict of interest. None of the authors have any competing interests in the manuscript.

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent to publish Not applicable.

References

Alagić SČ, Tošić SB, Dimitrijević MD, Antonijević MM, Nujkić MM (2015) Assessment of the quality of polluted areas based on the content of heavy metals in different organs of the grapevine (*Vitis vinifera*) cv Tamjanika. Environ Sci Pollut Res 22:7155–7175. https://doi.org/10.1007/s11356-014-3933-1

Aricak B, Cetin M, Erdem R, Sevik H, Cometen H (2019) The change of some heavy metal concentrations in Scotch pine (*Pinus sylvestris*) depending on traffic density, organelle and washing. Appl Ecol Environ Res 17(3):6723–6734. https://doi.org/10.15666/aeer/1703_67236734

Behrens DA, Koland O, Leopold-Wildburger U (2018) Why local air pollution is more than daily peaks: modelling policies in a city in order to avoid premature deaths. Cent Eur J Oper Res 26:265–286. https://doi.org/10.1007/s10100-018-0534-y

Boamah KB, Du J, Boamah AJ, Appiah K (2018) A study on the causal effect of urban population growth and international trade on environmental pollution: evidence from China. Environ Sci Pollut Res 25:5862–5874. https://doi.org/10.1007/s11356-017-0882-5

Bozdogan E (2016) Heavy metal concentration in leaves of *Melia azedarach* as a biomonitor of traffic-related air pollution. Oxid Commun 39:756–764

Burnett RT, Cakmak S, Brook JR (1998) The effect of the urban ambient air pollution mix on daily mortality rates in 11 Canadian cities. Can J Public Health 89:152–156. https://doi.org/10.1007/BF03404464

Cetin M, Sevik H, Cobanoglu O (2020) Ca, Cu, and Li in washed and unwashed specimens of needles, bark, and branches of the blue spruce (*Picea pungens*) in the city of Ankara. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-020-08687-3

Cetin M, Sevik H, Turkyilmaz A, Isinkaralar K (2021). Using Abies’s Needles as Biomonitors of Recent Heavy Metal Accumulation. Kastamonu University J Eng Sci 7(1):1–6. Retrieved from https://dergipark.org.tr/en/pub/kastamonujes/issue/63105/892118

Cheung CW, He G, Pan Y (2020) Mitigating the air pollution effect? The remarkable decline in the pollution-mortality relationship in Hong Kong. J Environ Eono Manage 101:102316. https://doi.org/10.1016/j.jeem.2020.102316

Christmann P (2018) Towards a more equitable use of mineral resources. Nat Resour Res 27:159–177. https://doi.org/10.1007/s11053-017-9343-6

Elsunousi AAM (2020) Temporal and spatial variation of air quality in Misurata, Kastamonu University Graduate School of Natural and Applied Sciences. MSc Thesis

Ewen C, Anagnostopoulou MA, Ward NI (2009) Monitoring of heavy metal levels in roadside dusts of Thessaloniki, Greece in relation to motor vehicle traffic density and flow. Environ Monit Assess 157:483–498. https://doi.org/10.1007/s10661-008-0550-9

Fiordelisi A, Piscitelli P, Trimarco B, Coscioni E, Laccarino G, Sorriento D (2017) The mechanisms of air pollution and particulate matter in cardiovascular diseases. Heart Fail Rev 22:337–347. https://doi.org/10.1007/s10741-017-9606-7

Greeger M, Prasd MNV, Hagemeyer J (1999) Metal availability and bioconcentration in plants. Heavy metal stress in plants. Springer, New York, 1–29

Grzędzicka E (2019) Is the existing urban greenery enough to cope with current concentrations of PM2.5, PM10 and CO2?. Atmos Pollut Res 10(1):219–233. https://doi.org/10.1016/j.apr.2018.08.002

Haiyan W, Stuanes AO (2003) Heavy metal pollution in air-water-soil-plant system of Zhuzhou City, Hunan Province, China. Water Air Soil Pollut 147:79–107. https://doi.org/10.1023/A:1024522111341

Hardiman RT, Jacoby B (1984) Absorption and translocation of Cd in bush beans (*Phaseolus vulgaris*). Physiol Plant 61:670–674

Hmeer AIA (2020) Bazı Bitkilerde Ağır Metal Konsantrasyonlarının Yetişme Ortamına Bağlı Değişimi, Kastamonu Üniversitesi Fen Bilimleri Enstitüsü Çevre Mühendisliği Anabilim Dalı, Yüksek Lisans Tezi, 53 sayfa

Hvidtfeldt UA, Sørensen M, Geels C, Ketzel M, Khan J, Tjønneland A, Raaschou-Nielsen O (2019) Long-term residential exposure to PM2.5, PM10, black carbon, NO2, and ozone and mortality in a Danish cohort. Environ Int 123:265–272. https://doi.org/10.1016/j.envint.2018.12.010

Isinkaralar O, Isinkaralar K, Ekizler A, Ilkdogan C (2017) Changes in the amounts of CO_2 and particulate matter in Kastamonu Province depending on weather conditions and locations. J Chem Biol Phys Sci 7(3):643–650. https://doi.org/10.24214/jcbsc.D.7.3.64350

Isinkaralar K (2020) Removal of formaldehyde and BTEX in indoor air using activated carbon produced from horse chestnut (*Aesculus Hippocastanum* L.) Shell. Ph.D. Thesis Hacettepe University

Institute of Science, Department of Environmental Engineering. Ankara, Turkey
Izah SC, Chakrabarty N, Srivastav AL (2016) A review on heavy metal concentration in potable water sources in Nigeria: human health effects and mitigating measures. Expo Health 8:285–304. https://doi.org/10.1007/s12403-016-0195-9
Khan A, Khan S, Qamar KMA, Z, Waqas M (2015) The uptake and bioaccumulation of heavy metals by food plants, their effects on plants nutrients, and associated health risk: a review. Environ Sci Pollut Res 22:13772–13799. https://doi.org/10.1007/s11356-015-4881-0
Kilicoglu C, Cetin M, Aricak B, Sevik H (2020) Site selection by using the multi-criteria technique-a case study of Bafra, Turkey. Environ Monit Assess 192(9):1–12. https://doi.org/10.1007/s10661-020-08562-1
Kilicoglu C, Cetin M, Aricak B, Sevik H (2021) Integrating multicriteria decision-making analysis for a GIS-based settlement area in the district of Atakum, Samsun, Turkey. Theor Appl Climatol 143:379–388. https://doi.org/10.1007/s00704-020-03439-2
Kim EH, Kim S, Lee JH, Kim J, Han Y, Kim YM, Ahn K (2015) Indoor air pollution aggravates symptoms of atopic dermatitis in children. PLoS One 10(3):e0119501. https://doi.org/10.1371/journal.pone.0119501
Krzyzanowski M, Apte JS, Bonjour SP, Brauer M, Cohen AJ, Prüss-Ustun AM (2014) Air pollution in the mega-cities. Curr Environ Health Rep 1:185–191. https://doi.org/10.1007/s40572-014-0019-7
Lee BJ, Kim B, Lee K (2014) Air pollution exposure and cardiovascular disease. Toxicol Res 30:71–75. https://doi.org/10.5487/TR.2014.30.2.071
Moćko A, Wacławek W (2004) Three-step extraction procedure for determination of heavy metals availability to vegetables. Anal Bioanal Chem 380:813–817. https://doi.org/10.1007/s00216-004-2832-6
Nadgórska-Socha A, Ptasiński B, Kita A (2013) Heavy metal bioaccumulation and antioxidative responses in *Cardaminopsis arenosa* and *Plantago lanceolata* leaves from metalliferous and non-metalliferous sites: a field study. Ecotoxicology 22:1422–1434. https://doi.org/10.1007/s10646-013-1129-y
Nagdeve DA (2004) Environmental pollution and control: a case study of Delhi Mega City. Popul Environ 25:461–473. https://doi.org/10.1023/B:POEN.0000036930.57805.36
Nouri J, Khorasani N, Lorestani B, Karami M, Hassani AH, Yousefi N (2009) Accumulation of heavy metals in soil and uptake by plant species with phytoremediation potential. Environ Earth Sci 59:315–323. https://doi.org/10.1007/s12665-009-0028-2
Ozturk S, Isinkaralar O (2018a) New Trends in Tourism: A Research on Farm Tourism. J Curr Res Social Sci 8(4):537–546. https://doi.org/10.26579/jocress-8.4.30
Ozturk S, Ayan E, Isinkaralar O (2018b) Visual landscape evaluation of kastamonu clock tower environment as a historical urban area. Fresen Environ Bull 27:12B:9617–9625
Petkova EP, Jack DW, Volavka-Close NH, Kinney LP (2013) Particulate matter pollution in African cities. Air Qual Atmos Health 6:603–614. https://doi.org/10.1007/s11869-013-0199-6
Piczak K, Leśniewicz A, Żyrnicki W (2003) Metal concentrations in deciduous tree leaves from urban areas in Poland. Environ Monit Assess 86:273–287. https://doi.org/10.1023/A:1024076504099
Ristorini M, Astolfi ML, Frezzini MA, Canepari S, Massimi L (2020) Evaluation of the efficiency of *Arundo donax* L. leaves as biomonitors for atmospheric element concentrations in an urban and industrial area of Central Italy. Atmosphere 11:226. https://doi.org/10.3390/atmos11030226
Saleh EAA (2018) Determination of heavy metal accumulation in some landscape plants, Kastamonu University Institute of Science Department of Forest Engineering, PhD. Thesis
Savas DS, Sevik H, Isinkaralar K, Turkyilmaz A, Cetin M (2021) The potential of using *Cedrus atlantica* as a biomonitor in the concentrations of Cr and Mn. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-021-14826-1
Sert EB, Turkmen M, Cetin M (2019) Heavy metal accumulation in rosemary leaves and stems exposed to traffic-related pollution near Adana-İskenderun Highway (Hatay, Turkey). Environ Monit Assess 191(9):1–12. https://doi.org/10.1007/s10661-019-7714-7
Sevik H (2012) Variation in seedling morphology of Turkish fir (*Abies nordmanniana* subsp. *bornmulleriana* Mattf). Afr J Biotechnol 11(23):6389–6395. https://doi.org/10.5897/AJB11.3340
Sevik H, Cetin M (2015) Effects of water stress on seed germination for select landscape plants. Pol J Environ Stud 24(2):689–693. https://doi.org/10.15244/pjoes/30119
Sevik H, Isinkaralar K, Isinkaralar O (2018) Indoor air quality in hospitals: the case of Kastamonu Turkey. J Chem Biol Phys Sci Sect D 9(1):67–73. https://doi.org/10.24214/jcbps.D.9.1.06773
Sevik H, Cetin M, Ozel HB, Pinar B (2019a) Determining toxic metal concentration changes in landscaping plants based on some factors. Air Qual Atmos Health 12(8):983–991. https://doi.org/10.1007/s11869-019-00717-5
Sevik H, Cetin M, Ozturk A, Ozel HB, Pinar B (2019b) Changes in Pb, Cr and Cu concentrations in some bioindicators depending on traffic density on the basis of species and organs. Appl Ecol Environ Res 17(6):12843–12857. https://doi.org/10.15666/aeer/1706_1284312857
Sevik H, Ozel HB, Cetin M, Özel HU, Erdem T (2019c) Determination of changes in heavy metal accumulation depending on plant species, plant organism, and traffic density in some landscape plants. Air Qual Atmos Health 12(2):189–195. https://doi.org/10.1007/s11869-018-0641-x
Sevik H, Cetin M, Ozel HB, Akarsu H, Cetin IZ (2020a) Analyzing of usability of tree-rings as biomonitors for monitoring heavy metal accumulation in the atmosphere in urban area: a case study of cedar tree (*Cedrus* sp.). Environ Monit Assess 192(1):23. https://doi.org/10.1007/s10661-019-8010-2
Sevik H, Cetin M, Ozel HB, Ozel S, Cetin IZ (2020b) Changes in heavy metal accumulation in some edible landscape plants depending on traffic density. Environ Monit Assess 192(2):78. https://doi.org/10.1007/s10661-019-8041-8
Sevik H, Cetin M, Ozel HU, Ozel HB, Mossi MMM, Cetin IZ (2020c) Determination of Pb and Mg accumulation in some of the landscape plants in shrub forms. Environ Sci Pollut Res 27(2):2423–2431. https://doi.org/10.1007/s11356-019-06895-0
Shahid M, Dumat C, Khalida S, Schreck E, Xiong T, Nabeel NK (2017) Foliar heavy metal uptake, toxicity and detoxification in plants: a comparison of foliar and root metal uptake. J Hazard Mater 325:36–58
Sharma RK, Agrawal M, Marshall FM (2008) Heavy metal (Cu, Zn, Cd and Pb) contamination of vegetables in urban India: a case study in Varanasi. Environ Pollut 154(2):254–263. https://doi.org/10.1016/j.envpol.2007.10.010
Solange C, Joana F, Carlos S, Carla C, Diogo L, Hélder R, Carlos B, Peter R, Ana IM, João PT (2014) Integrating health on air quality assessment—review report on health risks of two major European outdoor air pollutants: PM and NO_2. J Toxicol Environ Health Part B 17(6):307–340. https://doi.org/10.1080/10937404.2014.946164
Topacoglu O, Sevik H, Akkuzu E (2016) Effects of water stress on germination of *Pinus nigra* Arnold. Seeds Pak J Bot 48(2):447–453
Turkyilmaz A, Sevik H, Cetin M (2018a) The use of perennial needles as bio-monitors for recently accumulated heavy metals. Landsc Ecol Eng 14(1):115–120. https://doi.org/10.1007/s11355-017-0335-9
Turkyilmaz A, Sevik H, Cetin M, Ahmaida Saleh EA (2018b) Changes in heavy metal accumulation depending on traffic density in some

landscape plants. Pol J Environ Stud 27(5):2277–2284. https://doi.org/10.15244/pjoes/78620

Turkyilmaz A, Sevik H, Isinkaralar K, Cetin M (2018c) Using *Acer platanoides* annual rings to monitor the amount of heavy metals accumulated in air. Environ Monit Assess 190:578. https://doi.org/10.1007/s10661-018-6956-0

Turkyilmaz A, Cetin M, Sevik H, Isinkaralar K, Saleh EAA (2020) Variation of heavy metal accumulation in certain landscaping plants due to traffic density. Environ Dev Sustain 22(3):2385–2398. https://doi.org/10.1007/s10668-018-0296-7

United Nations (2019) Department of Economic and Social Affairs, Population Division. World population prospects. https://population.un.org/wpp/Download/Standard/Population/. Accessed 30 Dec 2020

Vermeulen R, Downward GS, Zhang J, Hu W, Portengen L, Bassig BA, Lan Q (2019) Constituents of household air pollution and risk of lung cancer among never-smoking women in Xuanwei and Fuyuan, China. Environ Health Perspect 127(9):097001. https://doi.org/10.1289/EHP4913

Vladimirovna Afanasyeva L, Ayushievna Ayushina T (2019) Accumulation of heavy metals and biochemical responses in Siberian larch needles in urban area. Ecotoxicology 28:578–588. https://doi.org/10.1007/s10646-019-02055-9

Yigit N, Sevik H, Cetin M, Kaya N (2016a) Determination of the effect of drought stress on the seed germination in some plant species. Water Stress in Plants. https://doi.org/10.5772/63197

Yigit N, Sevik H, Cetin M, Gul L (2016b) Clonal variation in chemical wood characteristics in Hanönü (Kastamonu) Günlüburun black pine (*Pinus nigra* Arnold. subsp. Pallasiana (Lamb.) Holmboe) seed orchard. J Sustain for 35(7):515–526. https://doi.org/10.1080/10549811.2016.1225512

Yigit N, Cetin M, Ozturk A, Sevik H, Cetin S (2019) Varitation of stomatal characteristics in broad leaved species based on habitat. Appl Ecol Environ Res 17(6):12859–12868. https://doi.org/10.15666/aeer/1706_1285912868

Zhang J, Zhao N, Liu C et al (2018) C:N:P stoichiometry in China's forests: from organs to ecosystems. Funct Ecol 32:50–60. https://doi.org/10.1111/1365-2435.12979

Zhao N, Yu G, Wang Q, Wang R, Zhang J, Liu C, He N (2020) Conservative allocation strategy of multiple nutrients among major plant organs: from species to community. J Ecol 108:267–278. https://doi.org/10.1111/1365-2745.13256

Zwolak A, Sarzyńska M, Szpyrka E, Stawarczyk K (2019) Sources of soil pollution by heavy metals and their accumulation in vegetables: a review. Water Air Soil Pollut 230:164. https://doi.org/10.1007/s11270-019-4221-y