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Changes in Cadmium (Cd) concentrations in some plants depending on traffic density

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Abstract

Cadmium (Cd) is an element that is toxic to living things at very low doses and it is one of the most important pollutants for the environment. Also, it is classified as a Type 1 carcinogen, and it has a long biological half-life so it is of great importance to monitor the change of Cd concentration in air. This study aimed to determine the variation of Cd concentrations in some plants depending on plant species, organs, and traffic density, evaluated to determine the most suitable species and organ. It can be used as a biomonitor in monitoring the change of Cd concentration. The scope of the study covered determining the variation of Cd concentration in organs of four different plants, *Aesculus hippocastanum, Tilia tomentosa, Catalpa bignoides,* and *Ligustrum vulgare,* respectively. These species were investigated depending on traffic density. From the result of the study, it was determined that *Aesculus hippocastanum* and *Tilia tomentosa* were the most suitable species to be used as biomonitors of Cd among the species.

Keywords: Air pollution; Biomonitor; Cadmium; Heavy metal; Traffic emissions.

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1. Introduction

The industrial and urbanization revolution have increased and diversified for the demands and needs of people in the last century (Das et al. 2021; Goossens et al. 2021). Growing population and accumulating pollutants have caused various pollution in the world (Wang et al. 2020; Ozturk et al. 2021). Higher levels of pollution were reached especially in densely urbanized and industrialized areas (Aunan and Wang 2014; Ozturk et al. 2020). The release of elements that are used as raw materials and also advanced chemical materials were used in polluting the environment for industry and urbanization purposes (Barles 2010; Isinkaralar 2020; Elsunousi et al. 2021). So, they affect direct and indirect air, water, and soil (Isinkaralar and Gullu 2017; Al-Dulaimi and Al-Taai 2021). Due to the accumulation of these pollutants, the discharge points that are not cleaned have become worse nowadays. In particular, the situation has been worse for air pollution, which is a global problem (Isinkaralar et al. 2015; Li et al. 2019). Air pollution is among the components of environmental pollution, which causes intense changes in the structure of the atmosphere, global climate change, and greenhouse gas effects.

Heavy metals are among the leading air pollutants which do not deteriorate and disappear easily in nature, also they can easily bioaccumulate in living bodies (Turkyilmaz et al. 2018). They have a toxic or carcinogenic effect even at low concentrations. Therefore, it is of great importance to monitor heavy metal concentrations in the air (Nagajyoti et al. 2020). Cadmium (Cd) is one of the most important heavy metals in terms of human and environmental health (Chellaiah,2018). So, it was classified as a Type 1 carcinogen by IARC (International Agency for Cancer Research) in 1993. The Cd is an element that is toxic to humans, animals, and plants (Moulis and Thévenod 2010). It includes phosphate fertilizers, detergents and refined petroleum derivatives, flue gases formed during industrial production stages (Kubier et al. 2019; Yuan et al. 2019). The Cd demonstrates toxic properties at very low doses and has a long biological half-life (Bhardwaj et al. 2021).

Most of the absorbed metal ions are retained by the roots of plants, but the remainder is held by pectin compounds and proteins (Sala et al. 2017). Simple or facilitated diffusion involving protein carriers or endocytosis carries out the transport of cadmium ions through membranes (Thévenod 2010). Growth inhibition, limitation of transpiration, changes of integration of cell membranes, reduced uptake of mineral elements, changes in the level of polyamines and phosphoinositide's, leaf chlorosis or necrosis, changes in cell ultrastructure, first in chloroplasts and drop of photosynthesis intensity occurs when the Cd is taken into its plants' structure (Sankaran & Ebbs 2008; Farid et al. 2013).

1.1. Purpose of study

This study aimed to determine the change of Cd concentrations in some plants. They were *Aesculus hippocastanum, Tilia tomentosa, Catalpa bignoides,* and *Ligustrum vulgare* which were used to determine the most suitable species and organ depending on plant species, organs, and traffic density. They were analyzed separately and the change of Cd concentration in the air was monitored.

2. Materials and Methods

2.1. Sample

The study was carried out in Samsun city. All samples were collected from areas that were high traffic (HTR), low traffic (LTR), and almost no traffic (NTR). Among the species that are frequently grown in Samsun city centers. They were collected from four plant species as *Aesculus hippocastanum* (Ah), *Tilia tomentosa* (Tt), *Catalpa bignoides* (Cb), and *Ligustrum vulgare* (Lv). The samples were collected from the last year's shoot, that is, the one-year-old part, towards the end of the vegetation season, at the end of September. They were brought to the laboratory after being bagged and labeled.

2.2. Method

This study was conducted using the experiment in a laboratory.

2.3. Procedure

The samples were separated into their organs as the bark and leaves. They were washed with pure water. The organs were coded considering the washing process, and they were labeled as follows: the washed leaf as "LFW", unwashed leaf as "LFUW", washed bark as "BW", unwashed bark as "BUW" and wood samples as "WD". They were put on hold 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 two weeks. The dried plant samples were ground into powder and weighed 0.5 g samples for microwave. 10 mL 65% HNO_3 was added to all the samples.

The prepared samples were then burned in a microwave device at 280 PSI pressure and 180°C for 20 minutes. After the procedures were completed, the tubes were removed from the microwave and left to cool. They were completed to 50 ml by adding ultra-pure water to the cooling samples. After the prepared samples were filtered through filter paper, they were read in the ICP-OES device at appropriate wavelengths. The resulting values were multiplied by the dilution factor and the Cd concentration was calculated in the study.

2.4. Analysis

The obtained data were evaluated with the help of the SPSS 22.0 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.

3. Results

3.1. Variation of Cd concentrations in species

The changes in the concentrations of Cd in individuals of *Aesculus hippocastanum* (Ah), *Tilia tomentosa* (Tt), *Catalpa bignoides* (Cb), and *Ligustrum vulgare* (Lv) species were tried to be determined in areas with heavy traffic, low density, and almost no traffic. The variation of Cd concentration was given based on species in Table 1.

Table 1

Change of Cd (ppb) concentration in species depend on traffic density

Species	NTR	LTR	HTR	F value
Ah	31.50	49.44	53.94 a	1.54 ns
Tt	15.36 A	38.17 AB	56.14 aB	3.57*
Cb	16.13 A	62.70 AB	94.59 bB	3.81*
Lv	47.28	68.08	30.60 a	3.02 ns
F value	1.25 ns	2.78 ns	4.95**	

Uppercase letters show horizontal direction, however, lowercase letters indicate vertical directions. *Significant at 0.05 level, **Significant at 0.01 level, ***Significant at 0.001 level, *ns* not significant.

According to the results of the analysis of variance (ANOVA), the variation based on species was not statistically significant (p>0.05). The lowest values in HTR were obtained in Ah, Tt, and Lv, while the highest values were obtained in Cb. When the location-based change in species was examined, the change of Cd concentration in Ah and Lv based on location was not statistically significant (p>0.05). In Tt and Cb, it is seen that the Cd concentration increases with the traffic density.

3.2. Variation of Cd concentration in organ

Table 2 below presents the change of Cd element according to organ and F value were obtained as a result of ANOVA test result.

Table 2

Change of Cd (ppb) concentration in organ depend on traffic density

Organ	NTR	LHTR	HTR	F value
LFW	23.06	55.07 a	60.15 ab	0.36 ns
LFUW	35.94 AB	49.80 aB	22.35 aA	6.03*
BW	17.41 A	46.68 aB	83.30 bC	5.81*
BUW	60.54	81.35 b	75.83 b	0.35 ns
WOOD	22.25	36.05 a	44.54 ab	2.79 ns
F value	0.17 ns	3.92**	2.74*	

Uppercase letters show horizontal direction; however, lowercase letters indicate vertical directions. *Significant at 0.05 level, **Significant at 0.01 level, ***Significant at 0.001 level, *ns* not significant.

According to the ANOVA, the organ-based change was not statistically significant (p>0.05). While the highest value in LHTR was obtained in BUW, other organs were in the same group. In HTR, the lowest values were obtained in LFUW, while the highest values were obtained in BW and BUW. When the change in organs based on location is examined, the change in Cd concentration based on location is statistically significant only in LFUW and BW (p<0.05). It is seen that the Cd concentration in BW increases with the traffic density.

3.3. Variation of Cr concentration in species and organ

Table 3 shows the change of Cd element according to species and organ and F value obtained as a result of ANOVA test result.

Table 3

Change of Cd (ppb) concentration in species and organ depend on traffic density

Species	Organ	Washing process	Traffic density			F value
			NTR	LHTR	HTR	
Ah	Leaf	+	Bl	68.96 gB	6.20 aA	294.79***
		-	70.26 e	76.53 g	LA	2.624 ns
	Bark	+	13.56 abA	30.53 abB	12.83 bA	168.39***
		-	12.83 abA	34.36 bcdB	124.00 kC	4275.69***
	Wood		29.33 dA	36.80 bcdA	72.73 hiB	34.20**
Tt	Leaf	+	Bl	41.86 cdeA	139.46 lB	224.19***

		-	20.46 bcA	44.13 deB	20.40 cdA	70.02***
	Bark	+	10.26 aA	31.66 abB	76.13 ijC	522.66***
		-	Bl	22.79 a	20.40 cd	3.27 ns
	Wood		Bl	50.40 efB	24.33 deA	189.39***
	Leaf	+	Bl	58.00 fA	80.93 jB	21.02*
		-	Bl	35.76 bcdB	17.93 bcdA	938.44***
Cb	Bark	+	Bl	Bl	185.00 m	
		-	16.13 abcA	123.66 hB	122.06 kB	275.13***
	Wood		Bl	33.36 bcA	67.03 hB	240.87***
	Leaf	+	23.06 cdB	51.46 efC	14.03 bcA	60.95***
		-	17.10 abcA	42.80 cdeC	28.73 eB	26.42**
Lv	Bark	+	28.40 dA	77.86 gC	59.26 gB	146.21***
		-	152.66 fB	144.60 iB	36.86 fA	151.34***
	Wood		15.16 abcA	23.66 aB	14.10 bcA	27.93**
F value			250.24***	114.56***	508.51***	

Bl: Below limit
Uppercase letters show horizontal direction; however, lowercase letters indicate vertical directions.
*Significant at 0.05 level, **Significant at 0.01 level, ***Significant at 0.001 level, *ns* not significant.

The ANOVA showed that the changes based on species and organ in all traffic densities were at a statistically significant level ($p<0.001$). Ah leaf +, Tt leaf +, Tt bark -, Tt wood -, except Cb bark + in Cb, was determined to be below the detectable limits for Cd concentration. The lowest value was Tt bark +, the highest value was in Ah leaf –, the lowest value in LHTR was Tt bark -, the highest value was Ah leaf -, the lowest value in HTR was Ah leaf +, the highest value was in CB bark + all results. In Ah leaf – and Tt bark was not statistically significant in species and organs based on traffic density. In Ah wood and Cb, it was determined that the Cd concentration in general increased with the traffic density. However, it can be said that the most suitable organs for the change of Cd concentration among these organs are Ah bark -, Tt leaf +, and Tt bark +.

4. Discussion

As a result of the study, it was determined that the concentrations of Cd in different species were at different levels, that is, the concentrations of Cd varied significantly based on species. In the studies on the accumulation of heavy metals in different plant species, it has been determined that the most important factor affecting the accumulation of heavy metals is the plant species. In many studies, it has been revealed that the change of heavy metal concentrations in plants grown in the same environment varies greatly (Turkyilmaz et al. 2018; Savas et al. 2021).

Heavy metal accumulation potential in plants varies depending on their growth performance and metabolic activities occurring in this process. The growth and development of plants are shaped by the interaction of genetic structure and environmental conditions (Turkyilmaz et al. 2020). Therefore, different levels of heavy metal accumulation in plants grown in the same environment are largely associated with different genetic structures.

From the result of the study, it was determined that *Aesculus hippocastanum* and *Tilia tomentosa* were the most suitable species to be used for monitoring Cd concentration. The Cd concentration of unwashed bark in *Aesculus hippocastanum* and washed leaf and bark in *Tilia tomentosa* increased with traffic density. In unwashed leaves, however, traffic density and Cd concentration change were not related due to particulate matter on the leaf. Heavy metals can hold onto the various particulate matter in the atmosphere after leaving their source, so particulate matter may contain a complex mixture of heavy metals (Shahid et al., 2017). Therefore, the effect of the washing process on the heavy metal concentration varies greatly depending on the heavy metal contamination of the particulate materials removed from the organ surface by washing (Sevik et al., 2020; Turkyilmaz et al. 2019). Therefore, it is not appropriate to use unwashed organs as biomonitors. 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 air pollution in cities and an increase in premature deaths (Uwak et al. 2021; Savas et al. 2021).

5. Conclusion

The change of Cd concentration on organ basis studies conducted to date have reported that heavy metal concentrations in different organs are at different levels, and this difference can even be tens of times. Heavy metal concentrations in different organs of plants grown in the same environment vary depending on factors such as the structure, morphology, surface area, surface texture, and size of the plant organ. The entry and accumulation of heavy metals in the plant structure are shaped by the effect of many factors. Plant-related factors such as plant species, genetic structure, and habitus, plant organ-related factors such as the structure, morphology, surface area, surface texture and size of the plant organ, environmental factors such as the amount of precipitation and moisture, heavy metal concentration in the soil, heavy metal concentration in the air, Heavy metal type, interaction with the plant, factors related to heavy metals such as exposure time and the interaction of many factors such as these play a role in the entry and accumulation of heavy metals into the plant body.

Consequently, it is known that today, environmental pollution is one of the most important problems in the world, this problem is growing gradually, and as a result of anthropogenic factors, especially industrial activities, vehicles, urbanization, soil, water, and air pollution have reached dimensions that threaten human health and ecosystem. Among the pollution components, air pollution is of greater importance due to its potential effects. Therefore, the improvement of air quality is currently one of the most important and priority issues. In this study, it was determined that *Tilia tomentosa* accumulated more Cd than other species and this accumulation was associated with traffic density. Therefore, besides the use of *Tilia tomentosa* as a biomonitor is important to monitor Cd pollution.

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