

CHANGES IN PB, CR AND CU CONCENTRATIONS IN SOME BIOINDICATORS DEPENDING ON TRAFFIC DENSITY ON THE BASIS OF SPECIES AND ORGANS

SEVIK, H.¹ – CETIN, M.^{2*} – OZTURK, A.³ – OZEL, H. B.⁴ – PINAR, B.⁵

¹*Department of Environmental Engineering, Faculty of Engineering and Architecture, Kastamonu University, Kastamonu, Turkey*

²*Department of Landscape Architecture, Faculty of Engineering and Architecture, Kastamonu University, Kastamonu, Turkey*

³*Department of Forest Engineering, Faculty of Forestry, Kastamonu University, Kastamonu, Turkey*

⁴*Department of Forest Engineering, Faculty of Forestry, Bartin University, Bartin, Turkey*

⁵*Department of Sustainable Agriculture and Natural Plant Resources, Institute of Science, Kastamonu University, Kastamonu, Turkey*

**Corresponding author*

e-mail: mcetin@kastamonu.edu.tr; phone: +90-366-280-2920; fax: +90-366-280-2900

(Received 11th May 2019; accepted 28th Aug 2019)

Abstract. The growing population and industrialization is causing air pollution. In some cities pollution has reached to a point where it is threatening human lives. Pollution has become one of the biggest issues of today's world. Pollutants are produced by exhaust gases, car wheels, and vehicles. Heavy metals (HM) are one of the major culprits that cause air pollution. This is due to the fact that HM can exist in the environment for a long time without deterioration, and their concentration in the atmosphere is ever-growing. They also tend to bioaccumulate. Therefore, determining HM concentration levels is crucial in terms of identifying risk zones and levels. Bioindicators are the most important determinants that can indicate the change in the concentration of HM in the atmosphere. This study aims to monitor the changes in Pb, Cr and Cu concentrations in the leaves, seeds and branches of cherry plum (*Prunus ceracifera*), horse chestnut (*Aesculus hippocastanum*), Tilia (*Tilia tomentosa*), European ash (*Fraxinus excelsior*) and Norway maple (*Acer platanoides*) species, which can be used for monitoring the traffic-induced HM concentration. We observed that the concentration of all the elements increased according to the traffic density, this is especially visible in the case of Pb and Cr.

Keywords: *heavy metal, biomonitoring, pollution, landscape plant, plant species, vehicle, urban road*

Introduction

The increasing number of people living in urban centers in addition to the increase in the world population in recent years has brought along many problems with it. This process causes the destruction of nature, pollution of air, water and soil, as well as the deterioration of the ecological balance (Cetin, 2015a; Cetin et al., 2017a, b, 2018a, b, c, d, e, 2019a, b; Yucedag et al., 2019; Bozdogan Sert et al., 2019; Cetin 2019; Varol et al., 2019a, b). Air pollution is one of the most serious problems of today (Aricak et al., 2019; Kaya, 2009; Kaya et al., 2009, 2018; Yucedag and Kaya, 2016, 2017; Yucedag et al., 2018; Bozdogan Sert et al., 2019; Cetin, 2019; Sevik et al., 2019a, b, c). In fact, it is stated that approximately 6.5 million people die every year due to air pollution (Cetin, 2015a; Cetin et al., 2018a; Cetin et al., 2019a, b; Cetin, 2019). Even in Turkey, where

air is considered to be quite clean compared to many other countries, 29 thousand people lost their lives in 2016 due to air pollution (Cetin, 2015a, b, c; Cetin et al., 2019a, b, 2018c, d, e).

Since heavy metals tend to bioaccumulate, and they may be toxic even in low concentrations, they are of particular importance among the air pollution culprits. Although micronutrients such as Mn, Zn, Cr, Cu, Fe and Ni are necessary for living organisms, including plants, higher levels of them can have detrimental effects. Metals such as Hg, Cd, As and Pb have serious toxic effects on organisms even at low levels (Shahid et al., 2017). Many studies were conducted on heavy metals due to the importance of the subject (Turkyilmaz et al., 2018a, b; Sevik et al., 2019a; Akarsu et al., 2019; Bozdogan Sert et al., 2019; Jawed and Abo Aisha, 2019).

Plants are often used as bioindicators in monitoring heavy metal concentrations. However, different heavy metals accumulate at different levels in different plant species and organs. For this reason, it is necessary to determine which plant organs have what levels of heavy metal accumulation, so they can be used as bioindicators. In this study, we aim to determine the traffic-induced changes of Pb, Cr and Cu concentrations in the leaves, seeds and branches of four different plant species.

Materials and methods

Materials

The study was conducted in the Kastamonu town center. Kastamonu town center is built within a valley as a general view, and it is where the traffic is the densest. Within the scope of the study, the samples were collected from the areas with dense traffic, with low density traffic, and with almost no traffic as well as the areas with no roadway within 50 m vicinity (Fig. 1).



Figure 1. Study region, traffic intensity, and sampling points

Kastamonu town center, where the samples are collected from within the scope of the study, with dense traffic is an area where a 4-lane highway passes through with 2 lanes on

each direction. In this area, the traffic is generally dense during the day. The areas with low-density traffic are en route to the main road but outside the town center where the traffic is flowing. Taskopru and Inebolu routes were selected as the areas with low-density traffic. There is a two-lane road in this area, the traffic is flowing and the traffic density is quite low compared to the town center. Kastamonu University campus area was selected as the area with no traffic, and the points, where there was no roadway found within 50 m vicinity, were selected from the campus area, and samples were collected from those points.

Within the scope of the study, samples were collected from cherry plum (*Prunus ceracifera*), horse chestnut (*Aesculus hippocastanum*), tilia (*Tilia tomentosa*), European ash (*Fraxinus excelsior*) and Norway maple (*Acer platanoides*) plant species, which are often used in landscaping works. The samples were taken from last year's shoots, namely the one-year-old parts. Seeds of horse chestnut were used as the seed, whereas the seeds of tilia, European ash and Norway maple were used together with their coat and wings. However, the fruit flesh of cherry plum was used together with the peel. The samples were collected at the end of vegetation season of 2017, in August, and were brought to the lab after being packed and labelled.

Method

The measurements of heavy metal analyses were made in 2018. The samples, which were taken to the lab after being collected and labelled, were subjected to a separation process by being laid on the cardboards. The leaves, branches and seeds were separated and grouped. Then the branches were broken to enable them to dry thoroughly, and the seeds were crushed. The crushing of the seeds was carried out using marble pieces, and no metal tool was used during this process. The prepared samples were placed in glass settle plates and they were re-labelled. The fruit flesh of plum fruits was separated from the seed and was taken into glass settle plates and labelled. The samples prepared in such way were kept waiting for 15 days to be come air-dried, and the lab was ventilated every day throughout this process.

The air dried samples were made fully dried in a drying-oven at 45 °C for a week. In the next step, the plant samples were pulverised into powder and each weighing 0.5 g, powdered samples were placed in tubes designed for microwave. 10 mL of 65% HNO₃ was added onto the samples. Fume cupboard was used during this process. The prepared samples were then burned at 280 PSI pressure and 180 °C in the microwave device for a period of 20 min. The tubes were removed from the microwave after the process was completed and left to cool down. The cooled samples were filled in until they reached 50 ml by adding deionized water. The prepared samples were read on the ICP-OES device at proper wavelengths after being filtered through the filter paper.

The data obtained were analyzed by using SPSS package program, and variance analysis was applied to the data. Homogeneous groups were obtained by applying Duncan test to the values with differences at 95% of confidence level statistically. The data obtained were interpreted after being simplified and tabulated.

Results

Change of Cr concentration depending on traffic density

Changes in Cr concentration of study samples were determined in the areas with no traffic, with low-density traffic and with dense traffic, and variance analysis and Duncan

test were applied to the data obtained. The mean values, F value and significance level obtained as a result of variance analysis, and homogeneous groups formed as a result of Duncan test are given in *Table 1*.

Table 1. Concentrations of Cr in plants and organelles in different vehicle flow paths

Species	Organ	Traffic density			F value
		No traffic	Low-density traffic	Dense traffic	
Cherry plum	Leaf	987.3 a	1470.3 b	1487.3 b	1217.820***
	Seed	1611.3 a	2283.0 b	2671.3 c	36.114***
	Branch	1069.6 a	1247.3 b	1827.6 c	334.763***
Horse chestnut	Leaf	2303.0 a	2357.0 b	7046.6 c	35179.582***
	Seed	443.3 a	653.0 b	910.6 c	24.926***
	Branch	721.6 a	1002.0 b	1635.6 c	87.183***
Tilia	Leaf	1058.9 a	1518.6 b	2148.9 c	1388.556***
	Seed	1051.9 a	1509.0 b	2134.9 c	103.211***
	Branch	706.6 a	825.3 b	996.3 c	149.214***
European ash	Leaf	548.5 a	1538.6 b	3538.4 c	11660.581***
	Seed	626.3 a	996.1 b	1366.0 c	363.166***
	Branch	476.6 a	733.6 b	1003.0 c	213.453***
Norway maple	Leaf	1174.3 a	1310.3 a	1739.6 b	54.594***
	Seed	951.0 a	992.6 a	1776.3 b	794.866***
	Branch	759.3 a	871.0 b	1001.3 c	21.065**

Significant at 0.01 level. *Significant at 0.001 level. The letters a, b, c, etc. mean according to Duncan test results show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a the numerical value grows

As a result of the variance analysis conducted, it was determined that the traffic-induced change in Cr concentration in all organs was statistically significant at minimum of 95% confidence level. When the mean values and the groups formed as a result of Duncan test are examined, it is seen that in all organs, the values obtained in the areas with no traffic are in the first homogeneous group, whereas the values obtained in the areas with dense traffic are in the last one. Therefore, we can surmise that the Cr concentration correlatively increases with traffic density

When the values are examined, we can observe that Cr concentration varies between the areas with no traffic and the areas with dense traffic in the same organs, as well as between different organs of the same species and the same organs of different species. The highest difference due to traffic density was determined in European ash leaves, and the value of 548.5 ppb in areas with no traffic increased up to 3538.4 ppb in areas with dense traffic, thus increasing by 6.5 times.

Change of Pb concentration depending on traffic density

Pb is one of the heavy metals most associated with traffic density. Within the scope of the study, the change in Pb concentration was determined for each factor, separately, and the mean values, F value and significance level obtained as a result of variance analysis, and the homogeneous groups formed as a result of the Duncan test are given in *Table 2*.

Table 2. Concentrations of Pb in plants and organelles in different vehicle flow paths

Species	Organ	Traffic density			F value
		No traffic	Low-density traffic	Dense traffic	
Cherry plum	Leaf	718.1 a	928.9 b	1432.2 c	367.932***
	Seed	605.3	1464.3	6801.0	1.654 ns
	Branch	1412.0 a	1565.3 b	2500.3 c	281.616***
Horse chestnut	Leaf	960.0 a	1209.3 b	2329.6 c	528.478***
	Seed	39.6 a	324.0 b	781.3 c	26.795**
	Branch	160.6 a	241.6 a	611.3 b	10.697*
Tilia	Leaf	769.0 a	934.0 b	1062.2 c	25.680**
	Seed	737.6 a	894.0 ab	1018.7 b	5.958*
	Branch	364.3	208.6	149.3	1.680 ns
European ash	Leaf	405.8 a	1112.2 b	2848.2 c	6723.160***
	Seed	165.9	202.3	238.7	4.078 ns
	Branch	603.6 a	727.3 a	1386.6 b	15.781**
Norway maple	Leaf	377.0 a	504.6 b	798.6 c	304.785***
	Seed	49.3 a	347.0 b	520.6 c	379.738***
	Branch	83.3 a	224.3 a	403.6 b	14.639**

*Significant at 0.05 level. **Significant at 0.01 level. ***Significant at 0.001 level. The letters a, b, c, etc. means according to Duncan test results; show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a numerical value grows

When the change of Pb concentration depending on the traffic density was examined, it was determined that the change of Pb concentration was statistically significant at a minimum of 95% confidence level in all the samples, except cherry plum and European ash seeds and tilia branches. When the mean values and homogenous groups formed as a result of Duncan test are examined, it can be observed that Pb concentration also correlatively increases with traffic density. As a result of the Duncan test, in all organs the values obtained in the areas with no traffic were in the first homogenous groups, whereas the values obtained in the areas with dense traffic were in the last one. When all values are examined, it is seen that the lowest value of 39.6 ppb is obtained in the horse chestnut seeds in the areas with no traffic, and the highest value of 6801 ppb is obtained in cherry plum seeds in the areas with dense traffic.

When the traffic-induced changes in the organs are examined, the ratio of the values obtained in the areas with dense traffic to the values obtained in the areas with no traffic is found to be lowest in the tilia seeds (approximately 1.38 times), and the highest ratio is found in the horse chestnut seeds (approximately 19.7 times).

Change of Cu concentration depending on traffic density

Changes in Cu concentration of study samples were determined in the areas with no traffic, with low-density traffic and with dense traffic, and variance analysis and Duncan test were applied to the data obtained. Afterwards, the mean values, F value and significance level obtained as a result of variance analysis, and homogeneous groups formed as a result of Duncan test are given in *Table 3*.

Table 3. Concentrations of Cu in plants and organelles in different vehicle flow paths

Species	Organ	Traffic density			F value
		No traffic	Low-density traffic	Dense traffic	
Cherry plum	Leaf	4.4 c	0.6 a	1.6 b	5310.500***
	Seed	5.0 a	5.3 a	45.3 b	31.705**
	Branch	1.0 a	9.2 b	13.4 c	6339.353***
Horse chestnut	Leaf	6.1 b	1.6 a	20.6 c	13329.150***
	Seed	0.3 a	0.8 a	2.9 b	70.408***
	Branch	3.2 a	7.7 b	8.7 c	146.478***
Tilia	Leaf	0.5 a	0.6 b	11.3 c	9368.455***
	Seed	13.4 a	16.6 a	286.5 b	140.116***
	Branch	6.2 b	6.2 b	2.4 a	228.071***
European ash	Leaf	7.5 a	10.5 b	36.9 c	117657.167***
	Seed	8.0 a	8.6 b	9.2 c	25.528**
	Branch	5.6 b	0.4 a	16.6 c	3122.898***
Norway maple	Leaf	3.3 a	3.5 a	7.1 b	831.267***
	Seed	14.4 a	17.3 b	20.0 c	492.818***
	Branch	4.8 a	7.9 b	11.6 c	807.474***

Significant at 0.01 level. *Significant at 0.001 level. The letters a, b, c, etc. mean according to Duncan test results show that the group is located. It is statistically different from the values contained in different groups, starting with the letter a the numerical value grows

When the change of Cu concentration depending on the traffic density is examined, it is seen that the traffic-induced change is statistically significant at a minimum of 95% confidence level in all organs, and that the Cu concentration correlatively increases together with the traffic density in general. While in 11 out of 15 study organs, the areas with no traffic were determined to be in the first homogeneous group, in 13 of them, the areas with dense traffic were in the last homogeneous group.

All in all, Cu concentration increases correlatively with traffic density in 11 out of 15 organs. While the minimum Cu concentration value of 0.3 ppm was obtained in the horse chestnut seeds in areas with no traffic, the highest value of 286.5 was obtained in Tilia seeds in the areas with dense traffic. However, other than this value, the maximum value was found to be 45.3 ppm.

Discussion

The study results showed that the elements subjected to study changed significantly on the basis of species. While the highest values of the metals other than Cu metal were obtained from the cherry plum, it was determined that the European ash was found in the first homogeneous group in all the metals. It was found that the concentrations of the metals subjected to study significantly varied among the species, and that sometimes the said difference was more than five times among the species.

In the studies carried out to date, it was found that the heavy metal concentration changed significantly on the basis of species. In his study, Mossi (2018) states that the difference between species is approximately twice more in Pb, which has a toxic effect even at low doses, approximately 2.75 times in Cr, which is one of carcinogenic

elements, and more than 5 times in Cu with toxic effects. Saleh (2018) states that the difference between species is more than 5 times in Cu, and even more than 24 times in Cd.

In the studies conducted, it is found that heavy metal concentrations change significantly on the basis of species, which means that different heavy metals are retained by different plants more intensely (Turkyilmaz et al., 2018a, b, c, d, 2019; Sevik et al., 2019a). This situation is primarily associated with the anatomical structure of the plant (Mossi, 2018; Saleh, 2018). The heavy metal intake of leaves varies depending on some factors such as the physical and chemical properties of the metals, their forms, morphology of the leaves, surface area, plant habitus next to the surface texture, heavy metals exposure time, environmental conditions and gas exchange (Beckett et al., 2000; Shahid et al., 2017; Turkyilmaz et al., 2018a, c; Sevik et al., 2019a; Mossi, 2018).

Within the scope of the study, it is found that heavy metal concentrations can change significantly on the basis of organs. However, the more important result is that the heavy metal concentrations in organs on the basis of species are different. For example, while the highest concentrations in Pb and Cr, which were some of the most important elements, were obtained in the seeds of *P. ceracifera* in the areas with dense traffic, they were obtained in the leaves of other species. However, the highest concentrations in Cu in the areas with dense traffic were obtained in the seeds of *P. cerasifera*, *T. tomentosa* and *A. platanoides*, while they were obtained in the leaves of *A. hippocastanum* and *F. excelsior*.

The change of heavy metal concentrations on the basis of organs became the subject of many studies as well. Mossi (2018) found organ differences between the leaf and branch organs, while Turkyilmaz et al. (2018d) and Turkyilmaz (2019) found it between bark and wood organs, Erdem (2018) and Sevik et al. (2019a) between leaf, seed and branch organs, and Elfantazi et al. (2018a, b) between the leaf and branch organs. Also in these studies, the heavy metal concentrations were found to be changing significantly on the basis of organ.

The main aim of the study is to determine the change of the elements subjected to the study depending on the traffic density. As a result of the study, it was determined that the concentrations of Pb and Cr elements correlatively increased with the traffic density in all organs of all species subjected to study, and the concentration of Cu element correlatively increased with traffic density in 11 out of 15 organs. Industrial and traffic activities are regarded as the most important sources of heavy metal pollution (Martley et al., 2004; Shahid et al., 2017; Erdem, 2018). In the studies conducted, it was found that the heavy metal concentrations in the plant organs changed significantly depending on the traffic density (Assirey et al., 2015; Galal et al., 2015; Saleh, 2018; Turkyilmaz et al., 2018a, b; Mossi, 2018; Sevik et al., 2019a; Akarsu et al., 2019; Jawed and Abo Aisha, 2019).

Cr, one of the heavy metals subjected to study, is one of the most toxic heavy metals in terms of potential toxicities and exposure to living organisms (Shahid et al., 2015, 2017). When taken into the human body through respiration, as it may cause nasal discharge, nasal bleedings, itching and perforation in upper respiratory tract it may also cause people, who are allergic to chromium, to get asthma attacks (Asri and Sonmez, 2006). As for plants, it is toxic for many high plants at the level of 100 mg/kg dry matter (Asri and Sonmez, 2006). Non-essential metals such as Cr are able to enter the plant leaves through leaf transfer (Shahid et al., 2017).

Within the scope of the study, it was found that Cr concentration ranged between 443.3 ppb and 7046.6 ppb. It was determined that the Cr concentration changed significantly depending on the traffic density, for example in the European ash leaves, and that the difference between the areas with no traffic and the areas with dense traffic was approximately 6.5 times.

Similar results were obtained in many studies conducted. Turkyilmaz et al. (2018b) reported that the Cr concentration was 16.595 ppm in the areas with no traffic, and that it increased up to 23.716 ppm in the areas with dense traffic. Sawidis et al. (2011) reported that the Cr concentration in the control group of *Platanus orientalis* leaves was 0.227 µg/g in Salzburg, 0.404 µg/g in Belgrade and 0.558 µg/g in Thessaloniki, while in polluted areas it increased up to 0.388 µg/g in Salzburg, 0.472 µg/g in Belgrade and 0.621 µg/g in Thessaloniki.

Pb, another element of the study, is of particular importance among heavy metals. Pb, which is widely used in industrial and agricultural activities, and thus is a common element, is a heavy metal which is emitted to the atmosphere as a metal or compound, and it is toxic in any case. Pb is one of the heavy metals that damages the ecological system most through human activities (Mossi, 2018; Erdem, 2018; Pinar, 2019).

Pb takes place near the top among the metals causing environmental pollution as well as being an important metal for people for many years (Mossi, 2018). Lead may be present more than normal levels especially in vegetable and food of animal origin grown in areas close to the town center and industrial zones (Kahvecioglu et al., 2007; França et al., 2017). In addition to these, lead-containing gasoline is an important resource as well (Pinar, 2019). Therefore, there are many studies available documenting the relationship between Pb and traffic density (Qing et al., 2015; Lei et al., 2015; Assirey et al., 2015; Galal et al., 2015; Begum et al., 2017).

Within the scope of the study, the Pb concentration was found to be ranging between 39.6 ppb and 6801 ppb. Aksoy and Sahin (1999) found that the average Pb concentration in the unwashed leaves of *E. angustifolia* was 180.21 µgg⁻¹ in industrial zones, 75.82 µgg⁻¹ by the roadside, 50.56 µgg⁻¹ in the town centre, 30.45 µgg⁻¹ close to the town, and 16.81 µgg⁻¹ in rural areas. Tam et al. (1987) found that the Pb concentration in the *Bauhinia variegata* leaves in Hon Kong was 12 µg g⁻¹ in the unwashed leaves of the control group, while it was as high as 276 µg g⁻¹ in the unwashed leaves by the roadside. Celik et al. (2005) reported that the average Pb content in *Robinia pseudoacacia* L. in Denizli province was 180.85 µgg⁻¹ in the samples collected from the industrial zone, 336.55 µgg⁻¹ in the samples collected from the urban roadsides, 74.86 µgg⁻¹ in the samples collected from outside the town center and 34.26 µg g⁻¹ in the samples collected from rural areas.

As a result of the study, the Cu concentration was found to be ranging between 0.3 ppm and 286.5 ppm and increased with traffic density, in general. Cu is quite an important element due to its involvement in enzyme activation, carbohydrate and lipid metabolisms within the plant body (Asri and Sonmez, 2006). Although different plant species need different amounts of copper, it is a highly toxic metal. Some effects of copper poisoning can be regarded as tissue damage, deterioration of roots and darkening of plant colour. Other effects are ion loss in the stem cells due to deterioration of membrane permeability and DNA damage due to deterioration of photosynthesis process (Okcu et al., 2009). Even though copper is an essential trace element for human and animal metabolism, acute copper intoxication may cause abdominal pain, nausea, vomiting and diarrhoea (Asri and Sonmez, 2006). Low levels of copper ion intake may

cause liver cirrhosis, Wilson's disease, systemic rheumatic diseases and kidney diseases, while high levels of copper ion intake may cause leukaemia (Hayta, 2006).

For this reason, many studies have been conducted on the determination of copper concentration in plants and its correlation with traffic density (Turkyilmaz et al., 2018a, b; Erdem, 2018; Mossi, 2018; Ozel, 2019). Turkyilmaz et al. (2018b) reports that the Cu concentration changes depending on the traffic density, and that Cu concentration, which is 69.615 ppb in areas with no traffic, increases up to 110.441 ppb in areas with dense traffic. Suzuki et al. (2009) states that Cu concentration in *Rhododendron pulchrum* leaves in Okayama, Japan goes up to 22.22 mg kg⁻¹, while Demirayak et al. (2011) state that the average Cu concentration in *M. grandiflora* leaves in Samsun province is around 35 ppm. Li et al. (2007) reports that Cu concentration in the leaves of *Sophora japonica* L. is higher in individuals by the roadside than individuals in the parks.

The studies conducted show that heavy metal concentrations are at different levels in plant species and organs depending on the traffic density. There are different reasons of this situation. First of all, traffic-induced heavy metal pollution in the atmosphere increases. This because the car wheels, vehicles, vehicle wear and exhaust gases in the urban areas cause heavy metals to be emitted into air (Zhuang et al., 2009; Schreck et al., 2012; Shahid et al., 2017; Turkyilmaz et al., 2018a). However, after emission into the atmosphere, heavy metals can be carried for miles away with the help of wind. In fact, studies conducted show that many heavy metals, especially Pb, can be carried far from their source (Uzu et al., 2009; Schreck et al., 2012; Shahid et al., 2017; Mossi, 2018). After the heavy metals are mixed into the atmosphere, the accumulation process within the plant is also very complex and under the influence of many factors. This process is primarily related to the structure of plant organs and heavy metals (Mossi, 2018; Erdem, 2018; Sevik et al., 2019a).

Accumulation of heavy metals within the plant body is closely related to environmental conditions as well. Heavy metals can be carried far from the source with the help of wind. Apart from this, environmental conditions have direct influence on the plant metabolism, and the entry of heavy metals into the plant structure is different within this process. It is also stated that there is a significant relationship between the entrance of heavy metals into the plant body and the air humidity and precipitation, in particular (Uzu et al., 2009; Schreck et al., 2012; Shahid et al., 2017; Mossi, 2018; Turkyilmaz et al., 2018a, b, c, d, 2019).

There are also some factors that are likely to affect the heavy metal concentration. For instance, the change in heavy metal concentration depending on the plant species was shown in this study as well as in others (Sevik et al., 2019a, b, c; Saleh, 2018; Erdem, 2018). However, heavy metal concentrations may be expected to be at different levels in the sub-types, forms, varieties and origins of plants. Likewise, many studies show that many phenological, morphological and anatomical structures vary according to these characteristics. In this case, it is inevitable for the plant metabolism to change and this situation to affect the heavy metal absorption (Sevik et al., 2012; Mossi, 2018).

The heavy metal absorption in plants is closely related to plant metabolism (Speak et al., 2012; Shahid et al., 2017). Therefore, it is possible for many factors, which affect the plant metabolism significantly such as the plant's stress level, (Sevik and Cetin, 2015; Sevik and Karaca, 2016), plant origin (Sevik et al., 2019a, c), chlorophyll content (Sevik et al., 2013; Cetin, 2017; Zeren et al., 2017; Zeren Çetin et al., 2018) and genetic

structure (Sevik, 2012), to affect heavy metal absorption, and hence heavy metal concentration in plants.

As a consequence, the change in heavy metal concentration in plants is the result of a complex mechanism due to the interaction of many factors (Mossi, 2018). However, the studies are not sufficient to gain a clear understanding of this mechanism, and thus to clearly reveal the factors affecting the change of heavy metal concentration. For this reason, studies on this subject should be increasingly continued and diversified.

Conclusions

Air pollution is one of the most important problems of today's world. Air pollution has gained a particular importance with the increase in the consciousness level in this field along with the population density in town centers, and many studies have been carried out to solve this important problem. Increasing green spaces is considered as one of the most effective methods among the solution proposals. The studies conducted showed that green spaces and the plants used in such spaces decreased the air pollution of all types and levels (Cetin et al., 2017a, b).

Plants can reduce air pollution significantly. However, the impacts of different species on different pollution factors are also at different levels. Although a large number of plant species have been the subject of studies to date, these studies are not at a sufficient level yet. There is no information on the heavy metal accumulation potentials of many plant species. However, great differences were determined between the heavy metal accumulating potentials of plant species in the studies conducted. For this reason, it is necessary to use the species, which have not been subjected to any study, in similar studies and to identify the plants, which are to be more effective in both monitoring and reducing the heavy metal pollution. Therefore, it can be recommended to continue and diversify similar studies.

One of the important results of the study is that some heavy metal concentrations are very high, especially in the seeds. For instance, heavy metal concentrations were found to be quite high in the seed of cherry plum. This shows that it can be highly risky to consume the plants grown in areas with high level of heavy metal concentration such as industrial zones and urban centers as food. However, the number of studies on this subject is not quite sufficient yet. Priority should also be given to the studies on this subject.

REFERENCES

- [1] Akarsu, H., Zeren Çetin, İ., Jawed, A. A., Abo Aisha, A. E. S., Cesur, A., Keskin, R. (2019): Changes of some heavy metal concentrations based on organic and traffic density in *Fraxinus excelsior* L.. – International Journal of Engineering, Design and Technology 1(1): 24-30.
- [2] Aksoy, A., Sahin, U. (1999): *Elaeagnus angustifolia* L. as a biomonitor of heavy metal pollution. – Turkish Journal of Botany 23: 83-87.
- [3] 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. – Applied Ecology and Environmental Research 17(3): 6723-6734.
- [4] Asri, F. Ö., Sonmez, S. (2006): Effects of heavy metal toxicity on plant metabolism. – Derim, Journal of West Mediterranean Agricultural Institute 23(2): 36-45 (in Turkish).

- [5] Assirey, E., Al-Qodah, Z., Al-Ahmadi, M. (2015): Impact of traffic density on roadside pollution by some heavy metal ions in Madinah city, Kingdom of Saudi Arabia. – *Asian Journal of Chemistry* 27(10): 3770-3776.
- [6] Beckett, K. P., Freer-Smith, P. H., Taylor, G. (2000): The capture of particulate pollution by trees at five contrasting urban sites. – *Arboricultural Journal* 24(2-3): 209-230.
- [7] Begum, H. A., Hamayun, M., Zaman, K., Shinwari, Z. K., Hussain, A. N. W. A. R. (2017): Heavy metal analysis in frequently consumable medicinal plants of Khyber Paktunkhwa, Pakistan. – *Pak J Bot* 49(3): 1155-1160.
- [8] Bozdogan Sert, E., Turkmen, M., Cetin, M. (2019): Heavy metal accumulation in rosemary leaves and stems exposed to traffic-related pollution near Adana-İskenderun Highway (Hatay, Turkey). – *Environmental Monitoring and Assessment* 191: 553. <https://rd.springer.com/article/10.1007/s10661-019-7714-7>
- [9] Celik, A., Kartal, A. A., Kaska, Y. (2005): Determining the heavy metal pollution in Denizli Turkey) by using Robinia pseudoacacia L. – *Environment International* 31: 105-112.
- [10] Cetin, M. (2015a): Determining the bioclimatic comfort in Kastamonu City. – *Environmental Monitoring and Assessment* 187(10): 640. <http://link.springer.com/article/10.1007/s10661-015-4861-3>.
- [11] Cetin, M. (2015b): Evaluation of the sustainable tourism potential of a protected area for landscape planning: a case study of the ancient city of Pompeipolis in Kastamonu. – *International Journal of Sustainable Development & World Ecology* 22(6): 490-495. <http://www.tandfonline.com/doi/abs/10.1080/13504509.2015.1081651?src=recsys&journalCode=tsdw20>.
- [12] Cetin, M. (2015c): Using GIS analysis to assess urban green space in terms of accessibility: case study in Kutahya. – *International Journal of Sustainable Development & World Ecology* 22(5): 420-424. <http://www.tandfonline.com/doi/abs/10.1080/13504509.2015.1061066?journalCode=tsdw20>.
- [13] Cetin, M. (2017): Change in amount of chlorophyll in some interior ornamental plants. – *Kastamonu University Journal of Engineering and Sciences* 3(1): 11-19. <http://dergipark.gov.tr/download/issue-file/5600>.
- [14] Cetin, M., Sevik, H., Isinkaralar, K. (2017a): Changes in the particulate matter and CO₂ concentrations based on the time and weather conditions: the case of Kastamonu. – *Oxidation Communications* 40(1-II): 477-485.
- [15] Cetin, M., Sevik, H., Saat, A. (2017b): Indoor air quality: the samples of Safranbolu Bulak Mencilis Cave. – *Fresenius Environmental Bulletin* 26(10): 5965-5970. http://www.prt-parlar.de/download_feb_2017/.
- [16] Cetin, M., Onac, A. K., Sevik, H., Canturk, U., Akpınar, H. (2018a): Chronicles and geoheritage of the ancient Roman city of Pompeiopolis: a landscape plan. – *Arabian Journal of Geosciences* 11(24): 798. DOI: 10.1007/s12517-018-4170-6. <https://link.springer.com/article/10.1007/s12517-018-4170-6>.
- [17] Cetin, M., Sevik, H., Yigit, N. (2018b): Climate type-related changes in the leaf micromorphological characters of certain landscape plants. – *Environmental Monitoring and Assessment* 190(7): 404. <https://doi.org/10.1007/s10661-018-6783-3>.
- [18] Cetin, M., Sevik, H., Yigit, N., Ozel, H. B., Aricak, B., Varol, T. (2018c): The variable of leaf micromorphological characters on grown in distinct climate conditions in some landscape plants. – *Fresenius Environmental Bulletin* 27(5): 3206-3211.
- [19] Cetin, M., Zeren, I., Sevik, H., Cakir, C., Akpınar, H. (2018d): A study on the determination of the natural park's sustainable tourism potential. – *Environmental Monitoring and Assessment* 190(3): 167. <https://doi.org/10.1007/s10661-018-6534-5>.
- [20] Cetin, M., Sevik, H., Canturk, U., Cakir, C. (2018e): Evaluation of the recreational potential of Kutahya Urban Forest. – *Fresenius Environmental Bulletin* 27(5): 2629-2634.

- [21] Cetin, M., Kalayci Onac, A., Sevik, H., Sen, B. (2019a): Temporal and regional change of some air pollution parameters in Bursa. – *Air Quality, Atmosphere & Health* 12(3): 311-316. <https://doi.org/10.1007/s11869-018-00657-6>.
- [22] Cetin, M., Adiguzel, F., Gungor, S., Kaya, E., Sancar, M. S. (2019b): Evaluation of thermal climatic region areas in terms of building density in urban management and planning for Burdur, Turkey. – *Air Quality Atmosphere & Health* 12 (9): 1103-1112. <https://link.springer.com/content/pdf/10.1007%2Fs11869-019-00727-3.pdf>
- [23] Cetin, M. (2019): The effect of urban planning on urban formations determining bioclimatic comfort area's effect using satellitia imagines on air quality: a case study of Bursa city. – *Air Quality, Atmosphere & Health* 2019: 1-13. Doi: 10.1007/s11869-019-00742-4. <https://rd.springer.com/article/10.1007/s11869-019-00742-4>
- [24] Demirayak, A., Kutbay, H. G., Kilic, D., Bilgin, A., Huseyinova, R. (2011): Heavy metal accumulation in some natural and exotic plants in Samsun City. – *Ekoloji* 20(79): 1-11.
- [25] Elfantazi, M. F. M., Aricak, B., Baba, F. A. M. (2018a): Changes in concentration of some heavy metals in leaves and branches of acer pseudoplatanus due to traffic density. – *International Journal of Trend in Research and Development* 5(2): 704-707.
- [26] Elfantazi, M. F. M., Aricak, B., Ozer Genc, C. (2018b): Concentrations in Morus Alba L. leaves and branches due to traffic density. – *International Journal of Current Research* 10(05): 68904-68907.
- [27] Erdem, T. (2018): The change of heavy metal concentrations in some plants due to species, organelles and traffic densities. – Master Thesis. Kastamonu University, Institute of Science, Department of Forest Engineering, Kastamonu, Turkey.
- [28] França, F. C., Albuerque, A. M., Almeida, A. C., Silveira, P. B., Crescêncio Filho, A., Hazin, C. A., Honorato, E. V. (2017): Heavy metals deposited in the culture of lettuce (*Lactuca sativa* L.) by the influence of vehicular traffic in Pernambuco, Brazil. – *Food Chemistry* 215: 171-176.
- [29] Galal, T. M., Shehata, H. S. (2015): Bioaccumulation and translocation of heavy metals by *Plantago major* L. grown in contaminated soils under the effect of traffic pollution. – *Ecological Indicators* 48: 244-251.
- [30] Hayta, A. B. (2006): the palce and importance of the family in the prevention of environmental pollution. – *Ahi Evran University Journal of Kirsehir Faculty of Education* 7(2): 359-376 (in Turkish).
- [31] Jawed, A. A., Abo Aisha, A. E. S. (2019): Usability of horse chestnut (*Aesculus hippocastanum* L.) as Biomonitor for monitoring some heavy metal concentrations caused by traffic. – *International Journal of Engineering, Design and Technology* 1(1): 16-23.
- [32] Kahvecioglu, Ö., Kartal, G., Güven, A., Timur, S. (2007): Environmental effects of metals-I. – www.metalurji.org.tr/dergi/dergi136/d136_4753.pdf (accessed on 19.04.2019).
- [33] Kaya, L. G. (2009): Assessing forests and lands with carbon storage and sequestration amount by trees in the State of Delaware, USA. – *Scientific Research and Essays* 4(10): 1100-1108.
- [34] Kaya, L. G., Cetin, M., Doygun, H. (2009): A holistic approach in analyzing the landscape potential: Porsuk Dam Lake and its environs, Turkey. – *Fresenius Environmental Bulletin* 18(8): 1525-153.
- [35] Kaya, L. G., Kaynakci-Elinc, Z., Yucedag, C., Cetin, M. (2018): Environmental outdoor plant preferences: a practical approach for choosing outdoor plants in urban or suburban residential areas in Antalya, Turkey. – *Fresenius Environmental Bulletin* 27(12): 7945-7952.
- [36] Lei, J., Hasi, E., Sun, Y. (2015): Assessing the Influence of Different Road Traffic on Heavy Metal Accumulation in Rural Roadside Surface Soils of the Eastern Ordos Plateau Grassland in China. – In: Aswathanarayana, U. (ed.) *Water Resources and Environment*. CRC Press, Boca Raton, FL, pp. 247-252.

- [37] Li, F. R., Kang, L. F., Gao, X. Q., Hua, W., Yang, F. W., Hei, W. L. (2007): Traffic-related heavy metal accumulation in soils and plants in Northwest China. – *Soil & Sediment Contamination* 165): 473-484.
- [38] Martley, E., Gulson, B., Pfeifer, H. R. (2004): Metal concentrations in soils around the copper smelter and surrounding industrial complex of Port Kembla, NSW, Australia. – *Science of the Total Environment* 325: 113-127.
- [39] Mossi, M. M. M. (2018): Determination of heavy metal accumulation in some shrub formed landscape plants. – PhD Thesis. Kastamonu University, Institute of Science, Department of Forest Engineering, Kastamonu, Turkey.
- [40] Okcu, M., Tozlu, E., Kumlay, A. M., Pehlivan, M. (2009): Effects of heavy metals on plants. – *Alinteri Journal* 17: 14-26 (in Turkish).
- [41] Ozel, S. (2019): The variation of heavy metal accumulation in some fruit tree organelles due to traffic density. – MsC Thesis. Kastamonu University, Institute of Science, Kastamonu, Turkey.
- [42] Pinar, P. (2019): The variation of heavy metal accumulation in some landscape plants due to traffic density. – MsC Thesis. Kastamonu University Institute of Science, Kastamonu, Turkey.
- [43] Qing, X., Yutong, Z., Shenggao, L. (2015): Assessment of heavy metal pollution and human health risk in urban soils of steel industrial city (Anshan), Liaoning, Northeast China. – *Ecotoxicology and Environmental Safety* 120: 377-385.
- [44] Saleh, E. A. A. (2018): Determination of heavy metal accumulation in some landscape plants. – Ph.D. Thesis. Kastamonu University, Institute of Science, Department of Forest Engineering.
- [45] Sawidis, T., Breuste, J., Mitrovic, M., Pavlovic, P., Tsigaridas, K. (2011): Trees as bioindicator of heavy metal pollution in three European cities. – *Environmental Pollution* 159: 3560-3570.
- [46] Schreck, E., Foucault, Y., Sarret, G., Sobanska, S., Cécillon, L., Castrec, R. M., Uzu Dumat, C. (2012): Metal and metalloid foliar uptake by various plant species exposed to atmospheric industrial fallout: mechanisms involved for lead. – *Science of the Total Environment* 427-428: 253-262.
- [47] Sevik, H. (2012): Variation in seedling morphology of Turkish fir (*Abies nordmanniana* subsp. *bornmulleriana* Mattf.). – *African Journal of Biotechnology* 11(23): 6389-6395.
- [48] Sevik, H., Cetin, M. (2015): Effects of water stress on seed germination for select landscape plants. – *Polish Journal of Environmental Studies* 24(2): 689-69.
- [49] Sevik, H., Karaca, U. (2016): Determining the resistances of some plant species to frost stress through ion leakage method. – *Fresenius Environmental Bulletin* 25(8): 2745-2750.
- [50] Sevik, H., Guney, D., Karakas, H., Aktar, G. (2012): Change to amount of chlorophyll on leaves depend on insolation in some landscape plants. – *International Journal of Environmental Sciences* 3(3): 1057-1064.
- [51] Sevik, H., Karakas, H., Karaca, U. (2013): Color - chlorophyll relationship of some indoor ornamental plant. – *International Journal of Engineering Science & Research Technology* 2(7): 1706-1712.
- [52] Sevik, H., Ozel, H. B., Cetin, M., Özel, H. U., Erdem, T. (2019a): Determination of changes in heavy metal accumulation depending on plant species, plant organism, and traffic density in some landscape plants. – *Air Quality, Atmosphere & Health* 12(2): 189-195. <https://doi.org/10.1007/s11869-018-0641-x>.
- [53] Sevik, H., Cetin, M., Ozturk, A., Yigit, N., Karakus, O. (2019b): Changes in micromorphological characters of *Platanus orientalis* L. leaves in Turkey. – *Applied Ecology and Environmental Research* 17(3): 5909-5921. http://dx.doi.org/10.15666/aeer/1703_59095921.
- [54] Sevik, H., Cetin, M., Ozel, H. B., Pinar B. (2019c): Determining toxic metal concentration changes in landscaping plants based on some factors. *Air Quality*

- Atmosphere & Health 12(8): 983-991. <https://doi.org/10.1007/s11869-019-00717-5>, <https://link.springer.com/content/pdf/10.1007%2Fs11869-019-00717-5.pdf>
- [55] Shahid, M., Khalid, S., Abbas, G., Shahid, N., Nadeem, M., Sabir, M., Aslam, M., Dumat, C. (2015): Heavy Metal Stress and Crop Productivity. – In: Hakeem, K. R. (ed.) Crop Production and Global Environmental Issues. Springer International Publishing, Switzerland, pp. 1-25.
- [56] Shahid, M., Dumat, C., Khalida, S., Schreck, E., Xiong, T., Nabeel, N. K. (2017): Foliar heavy metal uptake, toxicity and detoxification in plants: a comparison of foliar and root metal uptake. – Journal of Hazardous Materials 325: 36-58.
- [57] Speak, A., Rothwell, J., Lindley, S., Smith, C. (2012): Urban particulate pollution reduction by four species of green roof vegetation in a UK city. – Atmospheric Environment 61: 283-293.
- [58] Suzuki, K., Yabuki, T., Ono, Y. (2009): Roadside Rhododendron pulchrum leaves as bioindicators of heavy metal pollution in traffic areas of Okayama, Japan. – Environmental Monitoring and Assessment 149: 133-141.
- [59] Tam, N. F. Y., Liu, W. K., Wang, M. H., Wong, Y. S. (1987): Heavy metal pollution in roadside, urban parks and gardens in Hong Kong. – Science of the Total Environment 59: 325-328.
- [60] Turkyilmaz, A., Sevik, H., Cetin, M. (2018a): The use of perennial needles as biomonitors for recently accumulated heavy metals. – Landscape and Ecological Engineering 14(1): 115-120. <https://doi.org/10.1007/s11355-017-0335-9>.
- [61] Turkyilmaz, A., Sevik, H., Cetin, M., Ahmaida Saleh, E. A. (2018b): Changes in heavy metal accumulation depending on traffic density in some landscape plants. – Polish Journal of Environmental Studies 27(5): 2277-2284. <https://doi.org/10.15244/pjoes/78620>.
- [62] Turkyilmaz, A., Sevik, H., Isinkaralar, K., Cetin, M. (2018c): Using Acer platanoides annual rings to monitor the amount of heavy metals accumulated in air. – Environmental Monitoring and Assessment 190(10): 578. <https://doi.org/10.1007/s10661-018-6956-0>.
- [63] Turkyilmaz, A., Cetin, M., Sevik, H., Isinkaralar, K., Ahmaida Saleh, E. A. (2018d): Variation of heavy metal accumulation in certain landscaping plants due to traffic density. – Environment, Development and Sustainability. 1-14. <https://doi.org/10.1007/s10668-018-0296-7>.
- [64] Turkyilmaz, A., Sevik, H., Isinkaralar, K., Cetin, M. (2019): Use of tree rings as a bioindicator to observe atmospheric heavy metal deposition. – Environmental Science and Pollution Research 26(5): 5122-5130. <https://doi.org/10.1007/s11356-018-3962-2>.
- [65] Uzu, G., Sobanska, S., Aliouane, Y., Pradere, P., Dumat, C. (2009): Study of lead phytoavailability for atmospheric industrial micronic and sub-micronic particles in relation with lead speciation. – Environmental Pollution 157(4): 1178-1185.
- [66] Varol, T., Gormus, S., Cengiz, S., Ozel, H. B., Cetin, M. (2019a): Determining potential planting areas in urban regions. – Environmental Monitoring and Assessment 191(3): 157. DOI: 10.1007/s10661-019-7299-1.
- [67] Varol, T., Ertugrul, M., Özel, H. B., Emir, T., Çetin, M. (2019b): The effects of rill erosion on unpaved forest road. – Applied Ecology and Environmental Research 17(1): 825-839. http://www.aloki.hu/indvol17_1.htm.
- [68] Yucedag, C., Kaya, L. G. (2016): Effects of air pollutants on plants. – Mehmet Akif Ersoy University Journal of the Institute of Science and Technology 7(1): 67-74 (in Turkish).
- [69] Yucedag, C., Kaya, L. G. (2017): Recreational Trend and Demands of People in Isparta-Turkey. – In: Arapgirlioglu, H., Atik, A., Elliott, R. L., Turgeon, E. (eds.) Researches on Science and Art in 21 st Century Turkey. Chap. 104. Gece Publishing, Ankara.
- [70] Yucedag, C., Kaya, L. G., Cetin, M. (2018): Identifying and assessing environmental awareness of hotel and restaurant employees' attitudes in the Amasra District of Bartın. –

- Environmental Monitoring and Assessment 190(2): 60. <https://doi.org/10.1007/s10661-017-6456-7>.
- [71] Yucedag, C., Ozel, H. B., Cetin, M., Sevik, H. (2019): Variability in morphological traits of seedlings from five *Euonymus japonicus* cultivars. – Environmental Monitoring and Assessment 191(5): 285. DOI: 10.1007/s10661-019-7464-6.
- [72] Zeren, I., Cantürk, U., Yaşar, M. O. (2017): Change of chlorophyll quantity in some landscaping plants. – Journal of Bartın Faculty of Forestry 19(2): 174-182.
- [73] Zeren Çetin, İ., Cesur, A., Keskin, R., Akarsu, H. (2018): Variation of chlorophyll content in some landscape plants: a case study of Samsun. – Kastamonu University Journal of Engineering and Sciences 4(1): 1-10 (in Turkish). <https://dergipark.org.tr/download/article-file/609695>.
- [74] Zhuang, P., McBride, M. B., Xia, H., Li, N., Li, Z. (2009): Health risk from heavy metals via consumption of food crops in the vicinity of Dabaoshan mine, South China. – Science of the Total Environment 407: 1551-1561.