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Measurement of macronutrients and heavy metal concentrations in certain tree species exposed to pollution in Karabük

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Abstract

Anthropogenic pollution may have different forms and it can also affect air, water, soil, and plants. However, trees having significant bioaccumulative properties can reduce the air pollution. Measuring their capacity to accumulate macro elements and micro elements, the present study examined the tolerance of *Acer*, *Aesculus*, *Cupressus*, *Fraxinus*, *Pinus*, *Platanus*, *Populus*, and *Robinia* to air pollution in the Karabük province. Given the results observed in the present study, depending on the concentrations of tree leaves collected from the polluted and the unpolluted (control) areas, the order of macro elements was determined as Ca, K, S, Mg, and P, while the order of heavy metals was measured as Al, Fe, Mn, Zn, Ba, Pb, Br, Ni, Cu, and Co. Mean concentrations of Mg, K, and S were generally higher for the polluted trees, while Ca and P concentrations were higher in the control trees. The levels of trace elements and heavy metals were mostly higher for the polluted trees. Considering all data, it was seen that *Cupressus*, *Platanus*, and *Robinia* yielded the highest concentrations in terms of the parameters examined, while *Fraxinus* and *Pinus* species had the lowest concentrations. It can be stated that these tree species are useful in industrial areas having high pollution levels.

Keyword: Metal, Nutrients, Pollution, Trees, Karabük.

1. Introduction

Together with industrialization, heavy traffic, rapid population, and other human activities, the levels of atmospheric pollutants have increased, and this increase has negative effects on human health and natural ecosystems, as well as the microclimate (Nand et al. 2014). Contaminants may exist in various forms such as particulate matters (SO_2, NO/NO_2, CO/CO_2), aerosols, heavy metals such as Pb, Cd, I, and Fe (Baldacchini et al. 2017; Akbayır et al. 20190) arising from the intense traffic and factory dust (Turkyılmaz et al. 2020). The concentrations of those contaminants in the air depend on the wind speed, wind direction, temperature, and humidity, as well as the density of vegetation in the local area (Chen et al. 2014). With their leaf, bark, and branch surfaces, plants act as a sink for atmospheric pollutants and, therefore, roadside plants, highway vegetation, and also vegetation located nearby a factory around, especially established near major highways, are the primary victims of air pollution (Norouzi et al. 2015; Yener and Ay Ak 2019). They have a great potential to decrease the air pollution by trapping the pollutants thanks to their barrier functions. Besides the possible decrease in air pollution, they can also offer beneficial effects such as preventing the long- and short-term effects of exposure to pollutants on humans, as well as the stabilization of microclimate (Chen et al. 2014), noise pollution, and aesthetic appearance (Şevik et al. 2020a, 2020b; Bozkurt 2021). On the other hand, although these plants offer a reasonable solution to reduce the effects of air pollution, the differences in their tolerance to pollution raise the issue of "which species would be more useful in clearing the air pollution from functional and systematical aspects (Asad et al. 2019). Many studies demonstrated that resistant genotypes have a higher potential to capture the pollutants when compared to the susceptible ones (Nadgórska-Socha et al. 2016; Turfan et al., 2021). Moreover, the accumulation of heavy metals within the plant tissues varies significantly depending on the transporting speed of elements, their interactions with others, as well as plant genotypes. For instance; since mobile elements are easy-to-transport up to the leaf, their concentrations in the leaf are at a higher level, whereas the immobile elements are generally accumulated in the roots and stems (DalCorso et al. 2014). Moreover, the vegetation consisting of long-lived, low-maintenance, and also evergreen trees with larger size tend to filtrate pollutants more than others, possibly because of remarkably larger deposition areas (Zhang et al. 2017). For a species to be considered as a biomonitor in determining the effects of air pollution the species must first be widely present in that area and also the pollution must have a visible effect on the appearance of the plant (Shahid et al. 2016; Singh et al. 2017). Plant species commonly used in monitoring the level of contaminants in the air include *Acer*, *Aesculus*, *Cercis*, *Cupressus*, *Fraxinus*, *Pinus*, *Platanus*, *Populus*, *Robinia*, and *Quercus* (Eid et al. 2015; Kosiorek et al. 2017; Akbayır et al. 2019). Therefore, the present study aimed to determine the combined effects of pollution arising from Karabük-Kardemir Iron and Steel factories and the pollution arising from the heavy traffic on D-755 Highway by measuring the heavy metal concentrations, as well as other macro and micro elements in the leaves of eight tree species (*Acer negundo* L., *Aesculus hippocastanum* L., *Cupressus arizonica* subsp. *arizonica*, *Fraxinus excelsior* L., *Pinus nigra* subsp. *pallasiana*, *Platanus orinetalis* L., *Populus tremula* L. and *Robinia pseuduacaia* L.).

2.Material and Methods

2.1. Site Properties

This study was carried out in the Karabük province in the second week of July 2017. Karabük, located in the western Black Sea Region with a surface area of 4.145 km², lies between 40° 57' and 41° 34' northern latitudes and 32° 04' and 33° 06' east longitudes (Figure 1). Although this area is within the Black Sea climate zone, its distance from the coast prevents it from benefiting the humidity of this region. The annual mean temperature was 13.4°C (mean annual variation of 20.5°C), while the monthly mean temperature ranged between 23.1°C in July to 2.6°C in January. The climate is mostly mild and moist, with an annual rainfall of 600 mm, annual mean moisture of 74%, and an average wind velocity of 2.6 -km h^{-1}- (Dönmez et al. 2018).

This study area was chosen for two reasons: (1) Firstly, this route provides great opportunities to determine the combined effects of industrial and traffic-related heavy metals on the plants since Karabük Iron and Steel Factory and D-755 highway are located in the same area (Figure 1). While the D-755 with a length of approx. 132 km and having remarkably intense traffic is one of the few motorways connecting Western Black Sea coast- to inner regions, the Kardemir Karabük Iron and Steel Industry is the most important factory in Türkiye. Previously, it was shown by a number of studies that the concentrations of air pollutants; PM_{10}, SO_2, and NO_2 in Karabük were much higher than the WHO thresholds specified for health concerns (Çay et al. 2013; Dönmez et al 2018). Secondly, this route is also useful in measuring the man-made radioactive elements because the Kardemir-Karabük Iron and Steel Industry produces various products such as railway wheels, steel mill products, rolling mill runes, coke, and others (O_2, N, Ar), all of which can release heavy metals, particulate matters, cement dust, and artificial radioactive elements into the atmosphere (Fatih 2011; Geven et al. 2017).

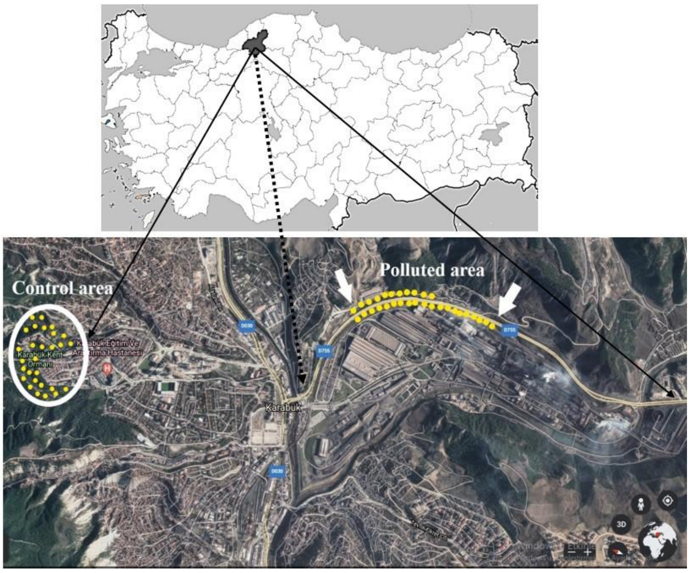

Figure 1: The control and polluted sample collection sites in Karabük Province. The polluted area is nearby the Karabük Iron Steel Factory on D755 highway (blue colour). The control area is 2450-3400 m away from the polluted area.

2.2. Collection of leaf samples

Eight tree species were examined in order to determine the heavy metal accumulation (Table 1). Furthermore, the sample trees nearby the factory were selected by considering the wind direction and from the locations, where the effect of pollution was thought to be at the highest level. As for the control sites, the fresh leaf samples were taken from the tree species growing further away (about 2450-3400 away) from the polluted area (Figure 2).

Table 1: Silvicultural characteristics of tree species studied in the polluted and control areas

Codes of Trees	Code of Trees	Species	Age (year)	Height (m)	Diameter at breast height (cm)	Used for sampling (number)
1	I	*Acer negundo* L.	6-8	8-10	10-12	8
2	II	*Aesculus hippocastanum* L.	9-10	9-11	12-13	7
3	III	*Cupressus arizonica* subsp. *arizonica*	10-11	10-13	13-16	8
4	IV	*Fraxinus excelsior* L.	6-8	10-12	12-13	8
5	V	*Pinus nigra* subsp. *pallasiana*	14-16	9-10	20-25	8
6	VI	Platanus orinetalis L	6-8	4-6	4-6	6
7	VII	*Populus tremula* L.	6-8	6-8	6-8	6
8	VIII	*Robinia pseuduacaia* L.	9-11	6-8	10-12	6

Considering that the reaction of species to air pollution may vary depending on age, developmental status, and leaf characteristics, homogeneity of tree characteristics such as height, diameter at breast height (dbh, 1.30 cm) and age and number of trees were taken into consideration during the selection of tree species (Table 1). While taking the leaf samples, fully maturated fresh leaves were collected from 8 tree species from the north, south, east, and west sides of each tree growing along the D-755 highway

(Fig. 2). The ages of trees in both study areas were determined using an increment borer. Diameter measurements were made by calibrating the diameter at breast height (DBH).

Figure 2: The sample trees growing along the roadside, near the iron/steel factory in Karabük

The heights of the trees were measured using TruPulse 360 Rangefinder equipment in the studied areas. After the sampling, the sampled leaves were cleaned using distilled water and then dried in an oven at 60ºC. The samples were later ground to powder using a laboratory blender.

2.3. Estimation of heavy metals
Elemental measurements of the ground leaf samples were performed using the SPECTRO brand's XEPOS model XRF instrument in Central Research Laboratory of Kastamonu University.

2.4. Statistical analysis
Analysis of variance (ANOVA) was applied for analyzing the differences in the heavy metal levels of leaf samples among the eight tree species collected in July and exposed to air pollution using the SPSS program (Version 11 for Windows). Following the results of ANOVAs, Tukey's honestly significant difference (HSD) test (α=0.05) was used for significance. The relationship between the measured characters was revealed by correlation analysis.

3. RESULTS AND DISCUSSION
3.1. Variation of macro nutrients in the leaf samples analysis
All plants need minerals, each of which is used at specific amounts, to complete their life cycle optimally. The elements generally found in larger amounts such as potassium (K), calcium (Ca), magnesium (Mg), including P phosphorus (P), and sulfur (S) are named macroelements (DalCorso et al. 2014; Wang et al. 2018), while the elements needed in very small amounts such as chlorine (Cl), chromium (Cr) cobalt (Co), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), nickel (Ni) and molybdenum (Mo) are named trace elements (Baycu et al. 2008; Maillard et al. 2015; Sing et al. 2016). In this study, the mean concentrations of macronutrients in the leaf tissues collected from the control and polluted areas are shown in Figure 3a-3d. The concentrations of Mg, P, S, K, and Ca (mg kg^{-1}) ranged among the tree species from 1101 (*C. arizonica)* to 7022 (*F. excelsior*), from 1454 (*C. arizonica*) to 2656 (*A. negundo*), from 1404 (*C. arizonica*) to 5283 (*P. tremula*), from 10430 (*C. arizonica*) to 22800 (*R. pseuduacaia*), and from 16540 (*P. nigra*) to 36500 (*A. negundo*) in the control areas, respectively, while they ranged from 2031 (*P. nigra*) to 9433 (*P. tremula*), from 1430 (*P. orientalis*) to 2519 (*R. pseuduacaia*), from 2960 (*C. arizonica*) to 12280 (*F. excelsior*), from 12300 (*C. arizonica*) to 28870 (*A. negundo*), and from 12650 (*P. nigra*) to 32940 (*F. excelsior*) in the polluted areas (Figure 3a-3d).

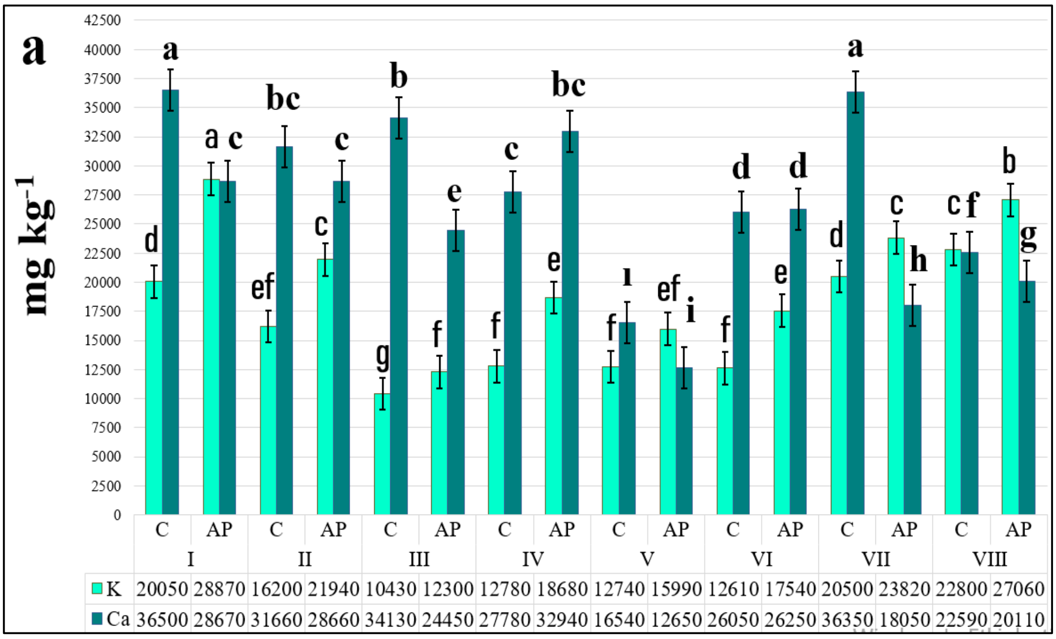

Figure 3a. 1: Mean concentrations of K and Ca the leaf samples from the eight tree species collected from the control (C) and the polluted areas (AP); 2: The code of trees (I-VIII); 3: The letters in the columns indicate p<0.001 significance

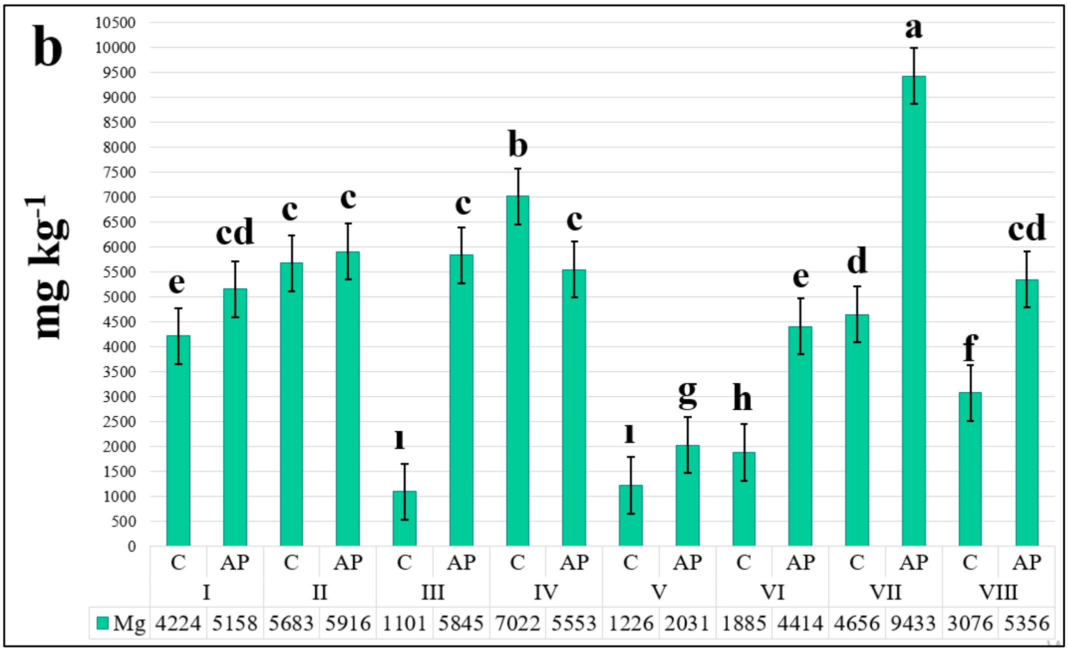

Figure 3b. 1: Mean concentrations of Mg the leaf samples from the eight tree species collected from the control (C) and the polluted areas (AP); 2: The code of trees (I-VIII); 3: The letters in the columns indicate p<0.001 significance

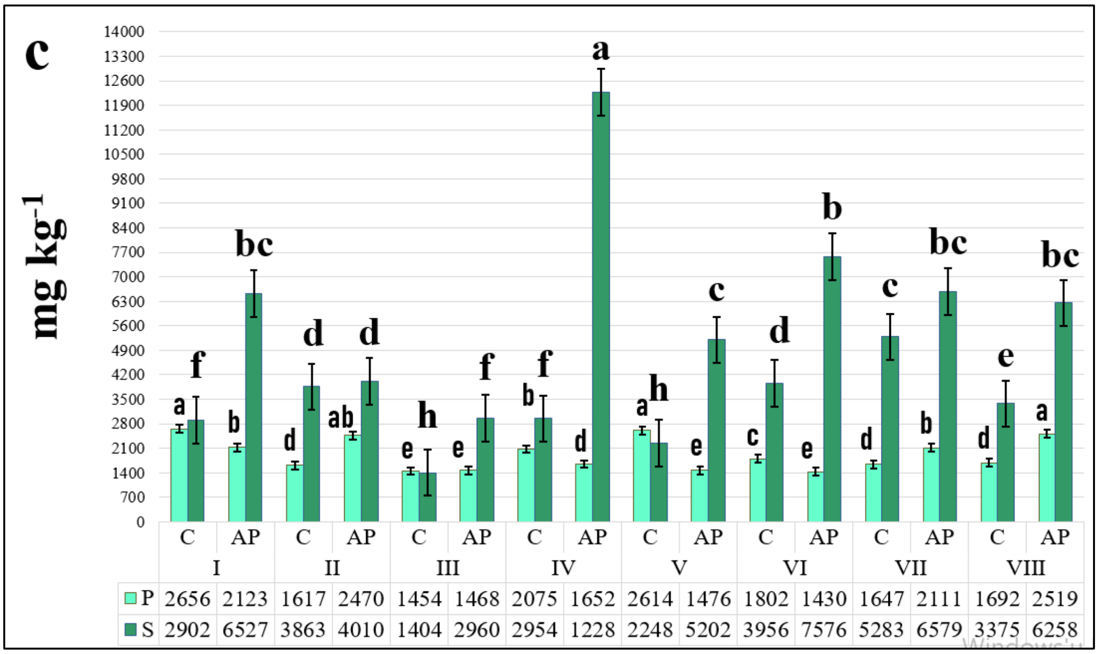

Figure 3c: 1: Mean concentrations of P and S the leaf samples from the eight tree species collected from the control (C) and the polluted areas (AP); 2: The code of trees (I-VIII); 3: The letters in the columns indicate p<0.001 significance

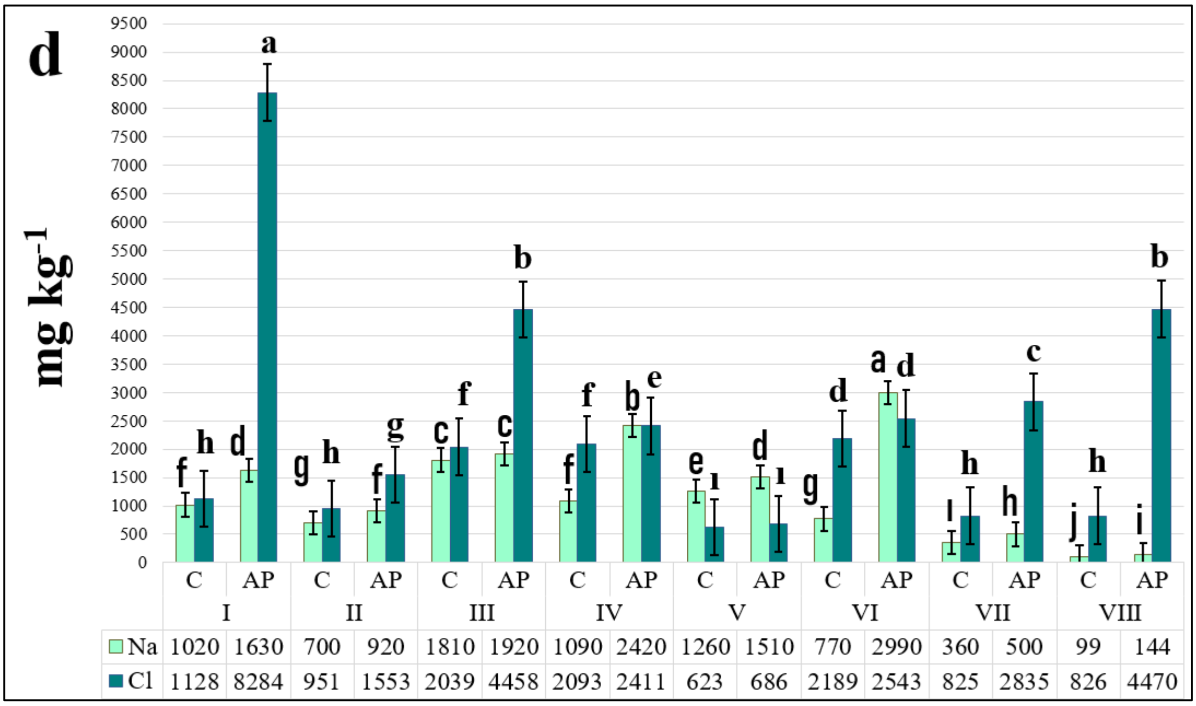

Figure 3d: 1: Mean concentrations of Na and Cl the leaf samples from the eight tree species collected from the control (C) and the polluted areas (AP); 2: The code of trees (I-VIII); 3: The letters in the columns indicate p<0.001 significance

As seen in Figure 3d, the concentration of Na among the eight tree species ranged from 99.0 to 1810 in the control areas, and from 500 to 2990 in the polluted areas, while Cl concentration varied between 686 and 8284 in the control areas, and between 623 and 2189 in the polluted areas. In the control group, the highest concentrations of P and Ca were recorded for Acer, while the highest Na concentration was found for *C. arizonica*, the highest Mg concentration for *F. excelsior*, and the highest S concentration *P. tremula* (Figure 3a-3d). Moreover, the concentrations of S and K were found to be high for all the control trees, whereas Mg concentration was only found to be high in the control tree of *F. excelsior* (Figure 3a-3d). The concentration of P in the leaves was lower for the polluted *A. negundo*, *F. excelsior*, *P. nigra*, and *P. orientalis* in comparison to the control leaves, whereas the Ca concentration was higher in the polluted *F. excelsior* and *P. orientalis* leaves (Figure 3a-3d). Na and Cl concentrations were high in trees that were exposed to the pollution (Figure 3d). High concentrations of macro elements such as K, Mg, P, and S in leaf samples could be explained by the high requirement of plants for these elements and also by the mobility properties of the elements (Maillard et al. 2015; Kumar et al. 2017). It is known that P, K, and Cl are called mobile elements for phloem, while Ca is defined as immobile, and S is defined to have variable mobility (Kopriva et al. 2019; Sardans and Penuelas 2021). In the present study, high concentrations of K, P, and Cl in the trees might be related to the easy transportation of these elements, while the high amount of Ca might be related to the high concentration of this element in the soil solution (Geilfus 2018; Kopriva et al. 2019). The result showed that the element found to have the highest concentration in the control trees was Ca, followed by K, Mg, S, P, Cl, and Na, whereas the element found to have the highest concentration in polluted trees was Ca, followed by K, S, Mg, Cl, Na, and P (Figure 3-5). The results are in parallel with the findings in the literature. DalCorso et al. (2014), Maillard et al. (2015), Kopriva et al. (2019), and Turfan et al. (2021) reported that Ca, K, Mg, P, and S were the most abundant element in the species from the contaminated and non-contaminated areas.

3.2. Variation in heavy metal concentrations in the leaf samples

Elements such as manganese (Mn), chlorine (Cl), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), and zinc (Zn), which can be absorbed by the root cells of plants as well as the stomata and epidermal layer of leaves, are required in trace concentrations for proper growth and development of plants (Brunner and Sperisen 2013; Nadgórska-Socha et al. 2016). However, these elements can cause irreversible damage to the tissues and cells if present in excessive concentrations. Moreover, some metals named non-essential such as Cr, As, Br, Ag, Cd, Sn, Sb, I, Ba, and Pb may also cause irreversible damage, even at very small concentrations (Baycu et al. 2008; Ghori et al. 2019; Akay 2022).

Table 2: Al, Cr, Mn, Fe, Co, Ni, and Cu concentrations (in mg kg^{-1}) in eight tree samples

		Al	Cr	Mn	Fe	Co	Ni	Cu
I	C	657 ± 5.0c*	3.5 ± 0.1e	129 ± 0.7d	340 ± 2i	4.8 ± 0.9b	15.2 ± 0.3d	9.4 ± 0.3c
	AP	1524 ± 9.0a	9.3 ± 0.2b	544 ± 1.1a	6980 ± 7b	10.4 ± 1.3a	18.0 ± 0.3bc	10.5 ± 0.3b
II	C	564 ± 5.0d	9.4 ± 0.2b	137 ± 1.0c	1246 ± 10g	8.1 ± 1.3ab	19.5 ± 0.3bc	14.1 ± 0.3b
	AP	932 ± 7.0b	7.4 ± 0.2c	226 ± 0.9b	3248 ± 5de	8.5 ± 1.3ab	27.9 ± 0.3a	18.8 ± 0.3a
III	C	869 ± 6.0b	4.6 ± 0.1d	41 ± 0.4g	516 ± 2ı	7.8 ± 1.3ab	9.1 ± 0.3e	7.3 ± 0.3c
	AP	1516 ± 8.0a	11.6 ± 0.2a	282 ± 1.0b	10460 ± 7a	10.2 ± 1.4a	12.7 ± .3e	11.2 ± 0.3b
IV	C	209 ± 2.4f	3.9 ± 0.1d	69 ± 0.5f	494 ± 2ı	7.0 ± 1.2b	7.9 ± 0.3e	14.6 ± 0.3b
	AP	962 ± 7.0b	6.2 ± 0.2c	234 ± 0.9b	5828 ± 7bc	5.3 ± 0.1b	9.2 ± 0.3e	16.1 ± 0.3ab
V	C	87.5 ± 1.1	4.5 ± 0.3d	77 ± 0.5e	161 ± 1j	1.3 ± 0c	10 ± 0.3e	6.0 ± 0.3d
	AP	746 ± 5.5c	7.3 ± 0.5c	149.0 ± 0.7c	2080 ± 4e	1.4 ± 0c	9.7 ± 0.3e	6.8 ± 0.3d
VI	C	921.7 ± 4.3b	5.0 ± 0.2d	96.7 ± 1.1e	488.5 ± 1ı	7.8 ± 0.4ab	8.8 ± 0.6e	8.1 ± 0.8c
	AP	377.6±3.8e	5.5 ± 0.2d	151.6 ± 1.6c	4866 ± 3c	8.5 ± 0.6ab	11.1 ± 0.8e	19.1 ± 1.2a
VII	C	274 ± 3.2f	3.4 ± 0.1e	199 ± 0.8b	732 ± 2.5h	4.9 ± 1.0b	16.7 ± 0.3d	11.3 ± 0.3b
	AP	336 ± 3.4e	4.0 ± 0.1d	228 ± 0.9b	3882 ± 6d	10.0 ± 1.5a	22.1 ± 0.3b	12.6 ± 0.3b
VIII	C	256 ± 7f	3.5 ± 0.2	144 ± 0.7c	1688 ± 4f	8.8 ± 1.2ab	18.3 ± 0.3bc	11.6 ± 0.3b
	AP	454 ± 4de	5.2 ± 0.2d	207 ± 0.8b	2312 ± 4e	9.8 ± 0.9a	18.6 ± 0.3bc	12.8 ± 0.3b
F.		682647.43	428.01	47517.16	37385982.15	587.31	107.11	2219.33
Sig.		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

*: Means indicated with different letters within same column are significantly different (P < 0.05).

Table 3: Zn, As, Br, Cd, I, Ba, and Pb concentrations (in mg kg^{-1}) in eight tree samples

		Zn	As	Br	Cd	I	Ba	Pb
I	C	25 ± 0.3g*	0.56 ± 0.0d	2.5 ± 0.0g	2.8 ± 0.2b	5.1 ± 0.6b	27.7 ± 1.2c	1.4 ± 0.0f
	AP	184 ± 0.5a	3.30 ± 0.2b	28.0 ± 1.2a	4.8 ± 0.4a	8.1 ± 1.2a	53.3 ± 1.5a	25.4 ± 0.8a
II	C	88 ± 0.6e	1.40 ± 0.1c	3.4 ± 0.0g	2.1 ± 0.0c	6.4 ± 0.7b	0.16 ± 0.0f	4.2 ± 0.0d
	AP	188 ± 0.4a	3.60 ± 0.2b	12.1 ± 0.0e	3.2 ± 0.2b	9.5 ± 1.3a	0.24 ± 0.0e	9.5 ± 0.3b
III	C	18.4 ± 0.2	0.60 ± 0.0d	13.8 ± 0.8e	1.6 ± 0.0d	4.6 ± 0.4c	27.8 ± 0.9c	2.2 ± 0.0e
	AP	117 ± 0.5d	8.40 ± 0.2a	25.0 ± 0.8b	2.4 ± 0.3c	6.7 ± 0.4b	40.8 ± 1.4b	20.2 ± 1.2ab
IV	C	25.7 ± 0.3g	0.55 ± 0.0d	16.0 ± 1.2d	1.3 ± 0.0e	4.3 ± 0.2c	1.8 ± 0.1d	2.3 ± 0.0e
	AP	88.7 ± 0.4e	2.4 ± 0.1b	20.0 ± 0.7c	3.2 ± 0.2ab	5.9 ± 0.6b	34.1 ± 1.4b	11.9 ± 0.5b
V	C	82.3 ± 0.4e	0.56 ± 0.0	1.5 ± 0.0h	1.2 ± 0.0e	3.5 ± 0.3c	1.4 ± 0.0d	2.1 ± 0.0e
	AP	81.8 ± 0.4e	2.5 ± 0.1b	7.7 ± 0.4f	2.3 ± 0.0c	5.5 ± 0.5b	29.8 ± 1.2c	11.2 ± 0.7b
VI	C	17.7 ± 0.7h	0.45 ± 0.0d	16.1 ± 0.8d	2.3 ± 0.2c	3.7 ± 0.2	27.4 ± 1.2c	2.1 ± 0.0e
	AP	40.9 ± 0.8f	1.10 ± 0.0c	17.3 ± 0.8d	2.6 ± 0.2b	5.7 ± 0.4b	37.7 ± 1.4b	5.2 ± 0.2d
VII	C	145 ± 0.6c	0.54 ± 0.0d	1.6 ± 0.0h	2.0 ± 0.2c	4.3 ± 0.2c	29.5 ± 1.6	2.5 ± 0.0e
	AP	226 ± 0.7a	0.65 ± 0.0d	9.7 ± 0.4f	2.8 ± 0.2b	11.6 ± 1.4a	36.4 ± 1.4b	5.4 ± 0.3d
VIII	C	90 ± 0.4d	0.80 ± 0.1c	2.4 ± 0.0g	1.6 ± 0.0d	3.2 ± 0.2c	0.18 ± 0.0f	2.2 ± 0.2e
	AP	106 ± 0.6d	3.80 ± 0.2b	10.0 ± f0.5	2.2 ± 0.2c	5.8 ± 0.6b	0.26 ± 0e	7.1 ± 0.3c
F		91.47	191691.01	2077.62	108.07	49.39	10379244.01	1369202.17
Sig.		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

*: Means indicated with different letters within same column are significantly different (P < 0.05)

In this study, the mean concentrations (in mg kg^{-1}) of Al, Cr, Mn, Fe, Co, Ni, and Cu ranged between 87.5-921.7 (*P. nigra - P. orientalis*), 3.4 and 9.4 (*P. tremula- A. hippocastanum*), 41 and 199. 161 (*C. arizoica - P. tremula*), 161 and 1688 (*P. tremula- P. nigra*), 1.3 and 8.8 (*P. nigra - R. pseudoacaia*), 7.9 and 19.5 (*F. excelsior- A. hippocastanum*), and 6.0 and 14. 6 (*P. nigra - F. excelsior*) in the control group and between 336 and 1524 (*P. tremula- A. negundo*), 4.0 and 11.6 (*P. tremula- C. arizonica*), 149 and 544 (*P. nigra- A. negundo*), 2080 and 10460 (*P. nigra - C. arizoica*), 1.4 and 10.4 (*P. nigra- A. negundo*), 9.2 and 27.9 (*F. excelsior- A. hippocastanum*), and 6.8 and 19.1 (*P. nigra- P. orientalis*) in polluted trees, respectively (Table 2). The recorded minimum and maximum values (in mg kg^{-1}) were 17.7 and 145.0 for Zn, 0.45 and 1.40 for As, 1.5 and 16.1 for Br, 1.2 and 2.8 for Cd, 0.16 and 29.5 for Ba, and 1.4 and 4.2 for Pb, respectively, in the control trees (Table 4). On the other hand, the minimum and maximum values found in polluted trees (in mg kg^{-1}) were 40.9 and 226.0 for Zn, 0.65 and 8.40 for As, 7.7 and 28.8 for Br, 2.3 and 4.8 for Cd, 5.5 and 11.6 for Ba, and 5.2 and 25.4 for Pb, respectively (Table 3). In the polluted location, the highest concentrations of Al and Mn were observed in *A. negundo*, while the highest concentration Ni was found in *A. hippocatanum* and the highest Cr, Fe, and Co concentrations in *C. arizonica*. Similarly, the highest Cu concentration was found in *P. orientalis* (Table 3). Moreover, the highest concentrations of Br, Cd, Ba, and Pb were found in *A. negundo*, whereas *C. arizonica* had the highest As concentration and *P. tremula* had the highest Zn concentration in the polluted location (Table 3). As seen in Tables 2 and 3, the element found to have the highest concentration in polluted samples was Fe, followed by Al, Mn, Zn, Ba, Br, Ni, Pb, Cu, I=Cr, Co, As, and Cd. However, the element having the highest concentration in the control samples was Fe, followed by Al, Mn, Zn, Ba, Ni, Br, Cu, Cr, Co, I, Pb, Cd, and As, respectively. In this study, among the heavy metals, Fe and Al were found to have the highest levels. The highest Fe concentration was observed in *C. arizoica, A. negundo,* and *F. excelsior*, while Al concentration was highest in *A. negundo*, *C. arizonica*, and *F. excelsior*, respectively (Table 2). Furthermore, the highest concentration of Cl was found in *A. negundo, C. arizonica*, and *R. pseudoacaia* (Table 2). Moreover, Acer was determined to have the highest concentrations of Cl, Al, Mn, Co, Pb, Br, Ba, and Cd, whereas highest levels of Fe, Cr, and As were observed in *C. arizonica*.

As shown Figure 2, the leaf samples had a scorched appearance, possibly due to morphological and biochemical degradation caused by toxic concentrations of these three elements originated from heavy traffic, factory dust, and high temperatures (Simon et al. 2014; Shahid et al. 2016). This result may be related to trees' tolerance to metals (Nand et al. 2014). In addition, although Fe, Zn, and Cu have low mobility and Mn is an immobile element, they act as essential minerals in metabolic and physiological processes (Maillard et al. 2015; Jain et al. 2020). Mn is generally found in expanding young parts of the plant due to the movement of meristematic tissues and resistant species accumulate more than 1 mg. Ni is mobile in plants and it can be accumulated at high levels in the leaves of several resistant species, which also accumulate Co. Cd, which is a toxic metal, is easily absorbed via the leaf cuticle, whereas the uptake of Pb occurs through the aerial parts of plants (Amari et al. 2017). It was determined that tolerant genotypes can accumulate several elements such as Fe, Al, Ni, Cl, and Mn, while the concentrations of As, I, Sn, and Cr in trees were generally lower than those of Fe, Mn, Al, Zn, Ni, and Cu (Chen et al. 2016; Baldacchini et al. 2017; Akbayır et al. 2019). Dadea et al. (2016), Baldacchini et al. (2017), Zhang et al (207) emphasized that the dust deposition between their leaves and branches of *Cupressus* may be at a higher level due to their cluster and fan-like structures. Similarly, Simon et al. (2014) investigated Fe, Al, Cu, Mn, Zn, Br, Ba, Ni, Pb, Cr, and As in *Acer, Quercus, Padus*, and *Celtis*, whereas Samecka-Cymerman et al. (2020) achieved the same findings in *Robinia, Alaimo, Varrica*, and *Ficus*.

As a result, the present study revealed that the trees' capacity to accumulate nutrients and heavy metals varied among the species. One of the reasons for using leaf samples as material in the present study is that the study area is suitable only for leaf sampling, whereas the other reason is that the symptoms of pollution, air pollution, and damage can be easily seen on the leaves. According to the results, the amounts of macronutrients Mg, K, and S were high for the polluted trees, while the amounts of Ca and P were high for the control trees. However, Mg concentration increased in *F. excelsior* and Ca concentration increased in *F. excelsior* and *P. orientalis* when compared to control. Trace elements and heavy metals were generally at higher levels in polluted trees. The highest essential element concentration in the control trees was found to be that of Ca, followed by K, Mg, S, P, Cl, and Na. However, the highest essential element concentration in the polluted trees was found to be that of Ca, followed by K, S, Mg, Cl, Na, and P. On the other hand, considering the heavy metals, the highest concentration was found to be that of Fe, followed by Al, Mn, Zn, Ba, Ni, Br, Cu, Cr, Co, I, Pb, Cd, and As in the control group, whereas the highest concentration was that of Fe, followed by Al, Mn, Zn, Ba, Br, Ni, Pb, Cu, I = Cr, Co, As, and Cd in polluted trees. Considering these findings, *C. arizonica*, *P. orientalis*, and *R. pseudoacacia* had the highest values in terms of the parameters examined, whereas *F excelsior* and *P. nigra* had the lowest values.

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