Global NEST Journal, Vol 22, No 3, pp 297-305

Heavy metal accumulation in shrubs used in roadside planting

Beklayalı N.[1*], and Gur M.[2]

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

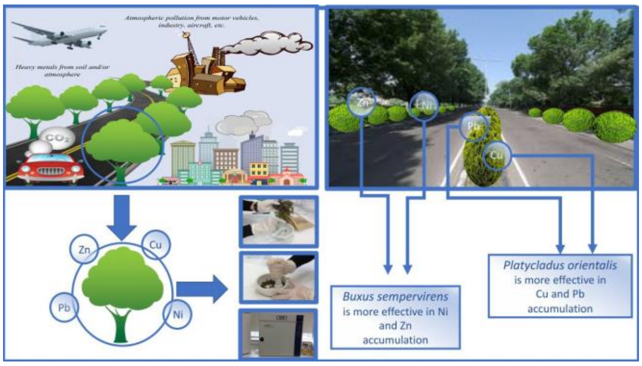
[2]Department of Forest Industrial Engineering, Kastamonu University Faculty of Forestry, Kuzeykent, Kastamonu, Turkey

Received: 25/04/2019, Accepted: 13/09/2020, Available online: 15/09/2020

*to whom all correspondence should be addressed: e-mail: nbelkayali@kastamonu.edu.tr

https://doi.org/10.30955/gnj.03140

Graphical abstract



Abstract

The aim of this study is to determine the shrub species which can be used as the biomonitor of air pollution originating mainly from the traffic and could provide the opportunity to increase the air quality in urban areas. To this end, *Berberis thunbergii*, *Buxus sempervirens*, *Juniperus horizontalis*, and *Platycladus orientalis,* mostly preferred species for roadside plantations, were chosen for the study. First, three regions with heavy traffic intensities were determined. Next, the levels of 4 heavy metals were examined by using Inductively Coupled Plasma–Optical Emission Spectrometry. The results obtained indicate that since the deposition of Cu and Zn is more in the leaves and barks of four species, these shrub species are more effective in the accumulation of Cu and Zn. Furthermore, the results of the study show that *Platycladus orientalis* is more effective in Cu and Pb accumulation, while *Buxus sempervirens* is more effective in terms of Ni and Zn accumulation. Determining high levels of traffic-originated heavy metals of Cu, Pb and Zn, particularly in the leaves of *Platycladus orientalis* in the city center indicates that air pollution is more intense in the city center and that *Platycladus orientalis* can be used as a biomonitor for traffic-originated air pollution.

Keywords: Air pollution, heavy metal accumulation, shrub, roadside plantation.

1. Introduction

It was stated in "*World Urbanization Prospects"* published by the UN that 55% of the world population lives in cities as of 2017. With the increase in urbanization, environmental problems increase and new cities that are estranged from nature emerge (Karagulian *et al.*, 2015). While the increase in urbanization due to increasing population causes ecosystem degradation in cities, open and green areas between the structure masses contributes positively to the quality of mental and physical life of the people in cities by playing an important part in the equalization of the relationship between human beings and the nature (Belkayalı and Güloğlu, 2019; Belkayalı and Ayan, 2018; Brown *et al.*, 2014; Richards *et al.*, 2017; Ummeh and Toshio, 2017). Plants that are used in roads which determine the direction of city's development, provide such contributions such as reducing the noise, creating a living space for wildlife, providing microclimate as well as providing aesthetic contributions such as setting a background for architectural structure of the city and screening the undesired sceneries (Forman, 2000; Kollarou and Kollaros, 2014; Perez *et al.*, 2016; Singh *et al.*, 2014). Urban roadside plantation takes on an important task in increasing the environmental quality by absorbing air-sourced pollutants (particulate matters, heavy metals, etc.), beyond all of these contributions.

Many pollutant matters emerge from exhaust gases, car wheels, vehicles and the vehicle abrasions in city roads. Barium (Ba), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Nickel (Ni), Lead (Pb) and Zinc (Zn) are among these pollutant matters (Dadea *et al.*, 2016; Fosu-Mensah *et al.*, 2017; Ogundele *et al.*, 2012; Pugh *et al.*, 2002). In recent years, lichens (Conti and Cecchetti, 2001), the leaves of tall plants (Aboal *et al.*, 2004; Ceburnis and Steinnes, 2000; Probst *et al.*, 2009) and barks of trunks (Mandiwana *et al.*, 2006; Sawidis *et al.*, 2011) have been used as biomonitors in order to monitor the traffic-originated air pollution. Furthermore, deciduous plant species along with evergreen plants, notably coniferous ones, are regarded as decent options for disposing of traffic-originated pollutions (Ceburnis and Steinnes, 2000).

It is important to determine the heavy metal concentrations in plants not only for monitoring the air quality and for disposing the heavy metals in the air by the plants, but also for determining the possibilities of using them as a device for increasing the air quality. As a consequence, many studies were conducted on the heavy metal accumulations in plants (Dadea *et al.*, 2016; Ekmekyapar *et al.*, 2012; Fosu-Mensah *et al.*, 2017; Levy *et al.*, 1999; Ogundele *et al.*, 2012; Opaluwa *et al.*, 2012; Pugh *et al.*, 2002; Rahul and Jain, 2016). These studies, however, mostly focused on tree species and the number of studies on shrub species are limited. Yet, shrub species are plants in which exhaust-sourced heavy metal accumulation can easily be monitored due to their such characteristics as growing faster and being closer to the exhaust ports because of their small size, and these species can be used even in limited areas. Shrubs are more preferred, especially in cities, to meet more community needs in small areas and to provide more effective use of the low-square meter green areas. That is the reason why the studies on shrubs are of more importance.

Therefore, it is important that the shrub species which can be an indicator of air pollution, one of the most important problems experienced in cities, be identified, and that the use of these species in urban road planting be ensured. And also, the lack of these type of studies increases the importance of this study.

The aims of this study can be expressed as: (1) researching the opportunity to use shrubs as a means of monitoring and increasing the air quality, (2) determining and comparing the heavy metal concentrations that were accumulated in the leaves of chosen species, (3) determining the difference between the amounts of heavy metals that were accumulated in leaves and barks in high-density traffic areas, (4) revealing the opportunities to use the species which has the most heavy metal accumulation in roadside plantation.

With this purpose, of the shrub species that are preferred the most in the roadside plantation in many regions of Turkey, 4 species, *Berberis thunbergii* (Japanese barberry), *Buxus sempervirens* (common box), *Juniperus horizontalis* (creeping juniper), *Platycladus orientalis* (oriental arborvitae) were chosen and leaf samples were taken in order to determine the accumulation of heavy metals such as Cu, Pb, Ni, Zn in the shrubs, depending on the changes in traffic density. Furthermore, for the determination of whether or not there is a change in the heavy metal accumulation ratios in the leaves and barks, leaf and bark samples were taken from the region where the traffic is most dense.

2. Materials and methods

2.1. Materials

The main material of the study consists of 4 shrub species; *Berberis thunbergii*, *Buxus sempervirens*, *Juniperus horizontalis*, *Platycladus orientalis*, the most preferred shrubs in the roadside plantation in Turkey. Within the scope of the study, the samples were collected from the city center where the traffic is dense, from Kuzeykent neighborhood where the traffic is not so dense but has dense usage rate and from the immediate surrounding of the city where there is almost no traffic density (Figure 1).

2.2. The Characteristics of the study area

Kastamonu, a city within the borders of Black Sea Region, was chosen as the study area (Figure 1). Latitude and longitude coordinates of the city are: 41.3766, 33.7765 (Kastamonu Map and Coordinates, 2018). According to the data from the Turkish Statistical Institute (TSI), the population of Kastamonu city center was 145.754 in 2017 (TSI, 2018). While Kastamonu city center had a population of 67.093 in 1965, its population has undergone a dramatic increase of 117% within 52 years. This increase in the population has negatively affected the city's ecosystem which has an important place in the natural and cultural source values. Kastamonu possesses an ancient history, and archaeological excavations and surface explorations indicate that the region witnessed settlements in Paleolithic, Neolithic, Chalcolithic periods to early Bronze Age without any interruption (Yıldız, 2013). Furthermore, forest lands of Kastamonu constitute 66.2% of the total land (GDF, 2015). When the number of vehicles that cause traffic density in the city center of Kastamonu was examined, it was seen that there were 128,663 registered vehicles according to the data of 2017 (TSI, 2018). In the measurements of The Ministry of Environment and Urbanization about the air quality that was conducted on city basis, there weren't any days that exceeded the limit value of Sulfur dioxide (SO_2) concentrations according to the values of World Health Organization and the number of days that exceeded the limit value of particulate matter (PM10) were determined as 149 (Chamber of Environmental Engineers, 2018).

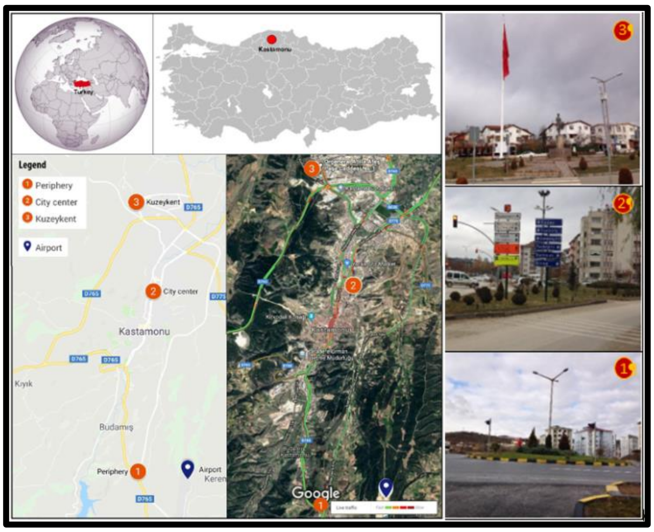


Figure 1. Location map of the study area and photographs of sampling points. Source: Mapdata © 2019 Google (https://www.google.com/maps/@41.397765,33.803447, 13z). Imagery ©2019 CNES/Airbus, DigitalGlobe, Landsat/Copernicus, Map data ©2019 Google

2.3. Methods

The leaves of the plants in 3 study areas and the barks of them in the city center were collected with the help of shear and glove, without touching by hands. Leaf samples were collected at the end of the growing season from plants that spent 1 growing season in the same region. Thus, it was aimed to determine the heavy metal accumulation in samples for one growing season. The collected leaf and bark samples were labeled by bagging them separately. The heavy metal analyses were conducted in the laboratories of Kastamonu University Central Research Laboratory Application and Research Center. The values that were obtained within the scope of the study were evaluated by comparing the amount of heavy metal that were typically found in the plants which were given in Table 1 and the amount of allowed heavy metal in the plants which was determined by WHO.

Table 1. Typical levels for heavy metals in plants (Hajar et al., 2014)

Heavy metals	Typical levels for heavy metals in plants (μg/g)	WHO permissible value of plant (μg/g)	Phytotoxic (μg/g)
Copper (Cu)	0.04-4.58	10	20-100
Lead (Pb)	0.3	2	30-300
Nickel (Ni)	0.01-0.37	10	
Zinc (Zn)	0.1-16	0.60	>100

**Target values are specified to indicate desirable maximum levels of elements in unpolluted soils*

Table 2. Heavy metal concentrations (ppm (μg/g)) in four shrub species leaves at each site

Shrub species		Periphery				City center				Kuzeykent district			
		Concentrations (ppm (μg/g))				Concentrations (ppm (μg/g))				Concentrations (ppm (μg/g))			
		Cu	Pb	Ni	Zn	Cu	Pb	Ni	Zn	Cu	Pb	Ni	Zn
Berberis thunbergii	mean	5,128	1,771	1,697	12,371	8,173	2,302	1,231	7,402	4,054	2,617	1,332	8,943
	sd	0.433	0.228	0.136	1.231	0.330	0.440	0.156	0.339	0.325	0.723	0.393	0.445
	rsd	0.845	1.288	0.798	0.995	0.404	1.914	1.269	0.458	0.801	2.764	2.950	0.498
Buxus sempervirens	mean	10,73	2,729	1,627	26,899	8,068	2,929	3,83	5,777	7,031	3,233	2,832	7,755
	sd	0.476	0.091	0.117	2.176	0.444	0.672	0.498	0.476	0.157	0.158	0.334	0.939
	rsd	0.444	0.335	0.719	0.809	0.551	2.294	1.300	0.823	0.223	0.490	1.181	1.211
Juniperus horizontalis	mean	5,02	1,252	0,665	4,985	4,65	2,163	1,507	5,564	4,014	2,298	1,338	7,362
	sd	0.609	0.146	0.254	0.165	0.389	0.491	0.359	1.021	0.612	0.366	0.290	0.238
	rsd	1.214	1.167	3.815	0.331	0.836	2.270	2.385	1.834	1.525	1.592	2.169	0.323
Platycladus orientalis	mean	3,78	3,048	1,261	8,377	11,759	3,494	2,041	13,406	7,779	3,216	2,178	9,294
	sd	0.618	0.588	0.168	0.306	0.991	0.179	0.081	0.975	0.559	0.398	0.315	0.419
	rsd	1.635	1.930	1.331	0.365	0.843	0.512	0.397	0.728	0.719	1.238	1.448	0.451

2.3.1. Heavy metal analysis

The concentrations (μg/ g) of Cu, Pb, Ni and Zn in the samples were analyzed by using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) with an Spectro Blue/Spectro. The samples were firstly homogenized sterilely by milling in a mill (Isolab). It was then dehydrated using the Microwave Burning System (Nüve FN 120 Dry Heat sterilizer/Ovens Milestone) (Figure 2).

Figure 2. Images of sample preparation

0.5 g of every sample was taken and then mixed with 7 mL HNO_3 (67% v/v) and 1 mL H_2O_2 (30% v/v) in reference to the application information of the device. To prepare blank solution, 7 mL of HNO_3 (67% v/v) and 1 mL of H_2O_2 (30% v/v) were placed in the empty microwave vessel and then were burned. The brims of the microwave containers were tightly closed and the temperature program for burning was adjusted. According to the temperature program, the samples were adjusted to 200 °C at 45 bar for the first 15 minutes, then were kept constant at 200 °C for 15 minutes. After the process, the solutions were cooled to room temperature. The samples which were then dissolved were taken up in flask and completed to 50 mL with ultra-purified water.

The standard stock solution (10 mg/L, periodic table mix 1, Sigma Aldrich) was used to prepare the calibration standards. The prepared samples and calibration solutions were analyzed on a SpectroBlue brand ICP-OES device.

2.3.2. Statistical analysis

Statistical calculations were made to determine whether there is a significant difference between the plant species and study areas selected within the scope of the study in terms of evaluating heavy metal accumulation. The obtained data were evaluated with Analysis of Variance–ANOVA in SPSS 17.0 package program and the results were evaluated reciprocatively in terms of heavy metal type, region, and plant species. For analyzing whether the independent variables of plant species (*Berberis thunbergii*, *Buxus sempervirens*, *Juniperus horizontalis* and *Platycladus orientalis)* and region (City center, Kuzeykent district, periphery) have a statistically significant effect on the concentration distribution of four heavy metals (Cu, Pb, Ni and Zn), Analysis of Variance–ANOVA was used. Whether or not there is a significant difference between the obtained results were determined according to the significance level of 0.05.

Table 3. The effect of plant species and the region on the concentration distribution of four heavy metals

		Plant species					Location				
		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Cu	Between Groups	91,862	3	30,621	6,696	,001*	40,626	2	20,313	3,393	,046*
	Within Groups	146,336	32	4,573			197,573	33	5,987		
	Total	238,198	35				238,198	35			
Pb	Between Groups	10,602	3	3,534	29,979	,000*	2,789	2	1,395	3,972	,028*
	Within Groups	3,772	32	0,118			11,586	33	0,351		
	Total	14,375	35				14,375	35			
Ni	Between Groups	13,223	3	4,408	13,645	,000*	4,511	2	2,255	3,907	,030*
	Within Groups	10,337	32	0,323			19,05	33	0,577		
	Total	23,561	35				23,561	35			
Zn	Between Groups	256,896	3	85,632	3,019	,044*	198,16	2	99,08	3,383	,046*
	Within Groups	907,798	32	28,369			966,534	33	29,289		
	Total	1164,69	35				1164,694	35			

**. The mean difference is significant at the 0.05 level.*

Table 4. Post Hoc Test Table

Plant species					Location				
Dependent Variable	**(I) Plant species**	**(J) Plant species**	**Std. Error**	**Sig.**	**Dependent Variable**	**(I) Location**	**(J) Location**	**Std. Error**	**Sig.**
Cu	*Buxus sempervirens*	*Berberis thunbergii*	1,0080801	,041*	Cu	City center	Kuzeykent	,9989199	,020*
	Juniperus horizontalis	*Buxus sempervirens*	1,0080801	,002*					
	Platycladus orientalis	*Juniperus horizontalis*	1,0080801	,016*					
Pb	*Berberis thunbergii*	*Buxus sempervirens*	,1618557	,000*	Pb	Periphery	City center	,2418952	,038*
	Buxus sempervirens	*Juniperus horizontalis*	,1618557	,000*					
	Juniperus horizontalis	*Platycladus orientalis*	,1618557	,000*		Kuzeykent	Periphery	,2418952	,012*
	Platycladus orientalis	*Berberis thunbergii*	,1618557	,000*					
Ni	*Berberis thunbergii*	*Buxus sempervirens*	,2679329	,000*	Ni	Periphery	City center	,3101840	,011*
	Buxus sempervirens	*Platycladus orientalis*	,2679329	,007*					
	Juniperus horizontalis	*Buxus sempervirens*	,2679329	,000*					
Zn	*Buxus sempervirens*	*Juniperus horizontalis*	2,5108071	,026*	Zn	Periphery	City center	2,2094085	,027*
						Kuzeykent	Periphery	2,2094085	,036*

**. The mean difference is significant at the 0.05 level.*

3. Results and Discussion

3.1. Results

The mean values of Cu, Pb, Ni and Zn, concentrations in the studied leaves were summarized as ppm (μg/g) in Table 2. It was seen that heavy metal content differs according to the area of the taken sample.

The highest metal amounts of *Berberis thıunbergii* leaves were detected for Cu in city center, for Pb in Kuzeykent district, and for Ni and Zn in periphery. The ranking of analyzed heavy metal concentration in *Buxus sempervirens* leaves were determined as follows: periphery> city center > Kuzeykent district for Cu, Kuzeykent district> city center > periphery for Pb; city center > Kuzeykent district> periphery for Ni and periphery> Kuzeykent district > city center for Zn. The levels of heavy metals detected in *Juniperus horizontalis* leaves were ordered Cu > Zn > Pb > Ni for periphery, and Zn > Cu > Pb > Ni for city center and Kuzeykent district. It was seen that among all values, the highest value for Zn was at Kuzeykent district. The ranking of analyzed heavy metal concentration in *Platycladus orientalis* leaves were determined as follows: city center > Kuzeykent district > periphery for Cu, Pb and Zn; Kuzeykent district> city center > periphery for Ni. (Table 2). As seen Table 2, *Berberis thunbergii*, *Buxus sempervirens*, *Juniperus horizontalis* and *Platycladus orientalis* leaves were behaved as a good collector for analyzed metals especially Cu and Zn.

According to the results of analyses, the highest Cu and Pb values were found in *Platycladus orientalis* (11,759 ppm (μg/g); 3,494 ppm (μg/g)) in city center, the highest Ni value was found in *Buxus sempervirens* (3,83 ppm (μg/g)) in city center and the highest Zn value was found in *Buxus sempervirens* (26,899 ppm (μg/g)) which was taken from the periphery (Table 2).

It was determined that the independent variables plant species (*Berberis thunbergii*, *Buxus sempervirens*, *Juniperus horizontalis* and *Platycladus orientalis)* and region (City center, Kuzeykent district, periphery) have a statistically significant effect on the concentration distribution of four heavy metals (Cu, Pb, Ni and Zn) according to the significance level of 0.05 (Table 3).

The result of the Post Hoc Test according to the significance level of 0.05 showed that while Cu, Pb and Ni concentration distribution differ significantly in all four shrub species, Zn concentration differ significantly only between Buxus sempervirens and Juiperus horizontalis (Table 4).

When the heavy metals analyses in the bark and leaves of the *Berberis thunbergii, Buxus sempervirens* and *Platycladus orientalis* were compared, Cu was significantly in higher concentrations in the bark. It was determined that in the bark of *Berberis thunbergii* and *Buxus sempervirens*, level of Zn was higher than its leaves had. Also, the study results showed that the barks of *Juniperus horizontalis* contained more Ni than its leaves did, and that the level of Pb in the barks of *Buxus sempervirens* and *Platycladus orientalis* were higher than their leaves (Figure 3).

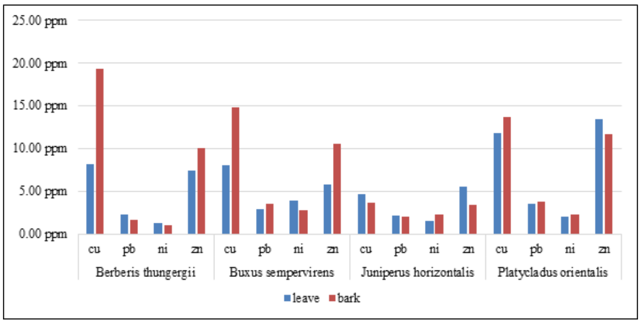


Figure 3. Heavy Metal Concentrations (ppm, (μg/g)) in the barks and leaves of four shrub species in the city center

When the amounts of heavy metal that are typically found in the plants, the amounts of allowed heavy metal in the plants which was determined by WHO, phytotoxic effect levels and the values that were obtained from the leaves as a result of the study were compared; it was determined that the amount of Cu in *Platycladus orientalis* in the city center and *Buxus sempervirens* outside of the city were higher than the allowed value 10 μg/g) of WHO. While Pb and Ni values were determined to be higher than the typical level (0.3 μg/g; 0.37 μg/g) in all of the four species, it was observed that Pb value was higher than the value that was determined by WHO (2 μg/g) except for *Juniperus horizontalis*. It was observed that Zn value was higher than the allowed level (0.60 μg/g) that was determined by WHO in all of the four species. As a result of the measurements, it was determined that none of the plants possessed a level of heavy metal that would cause a phytotoxic effect. According to the measurement results of samples that were taken from the barks of four plant species in the city center, it was determined that except for *Juniperus horizontalis*, the amount of Cu was much higher than the typical level (4.58 μg/g) and the allowed level (10 μg/g) determined by WHO and *Berberis thunbergii* was too close to the phytotoxic effect level (20 μg/g). Pb and Ni values were determined to be higher than the typical level (0.3 μg/g; 0.37 μg/g) in all of the four species. It was observed that Zn value was higher than the allowed level (0.60 μg/g) of WHO in all of the four species, as it was also in leaves (Table 1).

3.2. Discussion

Air pollution is one of the most important problems that threaten human health. Several studies were conducted in order to solve this problem. A part of these studies are comprised of studies that search for the possibility of using plants for monitoring and increasing the air quality. One of the factors that cause air pollution is heavy metals, and a large part of these heavy metals are oscillated due to human activities. Highways, mine sites, landfills and especially urban areas where human activities are dense are the important sources of heavy metals that are oscillated to the air. The studies conducted so far demonstrated that the heavy metal accumulation is seen more in plants in these areas (Dadea *et al.*, 2016; Ekmekyapar *et al.*, 2012; Fosu-Mensah *et al.*, 2017; Ogundele *et al.*, 2012; Opaluwa *et al.*, 2012; Pugh *et al.*, 2002; Rahul and Jain, 2016). In this study, Kastamonu city center selected as the study area since urban areas are one of the important sources of heavy metals. In order to determine the effect of heavy metal sources on plants, 4 shrub species and 3 areas with different usage densities were selected. The reasons for choosing shrub species in the study are that the exhaust pipes of the vehicles that cause heavy metal emission, and that the shrubs are at approximately the same height and therefore it is predicted that they were exposed to heavy metals more, and that the selected shrub species have not been studied in studies on this subject yet.

There are different heavy metal sources in 3 different areas where samples are collected. Samples were taken from plants at approximately the same distance from the road in order to demonstrate the effect of heavy metal sources caused by traffic on plants more clearly. Similar approaches have been observed in studies that were conducted on tree species (Ataabadi *et al.*, 2010; Fosu-Mensah *et al.*, 2017; Liang *et al.*, 2017; Ogundele *et al.*, 2015; Sulaiman and Hamzah, 2018; Ugolini *et al.*, 2013).

One of the studies that were conducted in order to determine which plants to be used as a biomonitor in the determination of air quality is the study of Pugh *et al.* (2002). Pugh *et al.* (2002) states that Ledum is a decent indicator plant for Pb, and that Salix is a good indicator plant for Zn and Cd. In this study which was conducted in Kastamonu, *Berberis thunbergii, Buxus sempervirens, Juniperus horizontalis*, and *Platycladus orientalis* leaves and barks behaved as a good collector for analyzed metals especially Cu and Zn. Also, among the four species tested in this study, levels of Pb and Cu in *Platycladus orientalis* and levels of Zn and Ni in *Buxus sempervirens* were the highest than the others. Therefore, *Platycladus orientalis* appears to be the most efficient accumulator of Pb and Cu among the four plants tested and may have the potential to be used as an indicator for Pb and Cu contamination in this region, while *Buxus sempervirens* appears as the most efficient accumulator of and indicator for Zn and Ni.

Although many studies were conducted on the usage of plant leaves as a biomonitor, there is a limited number of studies that were conducted on using barks as a biomonitor. In their study, Sawidis *et al.* (2011) and Mandiwana *et al.* (2006) state that heavy metal retention is higher in barks than leaves. The results of the study in Kastamonu indicated that Cu value was higher in *Berberis thunbergii*, *Buxus sempervirens* and *Platycladus orientalis* barks compared to the leaves.

Pb is not one of the main elements for plants, and since there are generally low amounts of Pb in soil, Pb levels that are determined in plants are good indicators for the determination of air quality (Kocić *et al.,* 2014; Liang *et al.*, 2017; Pugh *et al.*, 2002; Turer *et al.*, 2001). Determining high amounts of Pb level in the barks and leaves of *Platycladus orientalis* indicates that *Platycladus orientalis* can be helpful for heavy metal retention and can be used as an indicator of air pollution.

Ugolini *et al.* (2013), Dam-o (2015), Dadea *et al.* (2016) and Sulaiman and Hamzah (2018) hypothesize that plants' metal deposition capacity is connected to the surrounding environmental characteristics and the distance of plants from the source of pollution. Liang *et al.* (2017) measured concentrations of heavy metals (Cu, Zn, Pb and Cd) in leaves of twelve plant species from seven different locations in Shanghai, China. The results showed that the highest metal contents were found in the city center. Likewise, Sawidis *et al.* (2011) measured concentrations of four heavy metals in tree leaves and bark (Platanus orientalis L. and Pinus nigra Arn.,) from polluted and non-polluted areas of three European cities (Salzburg, Belgrade and Thessaloniki). The results show that selected plants have a higher efficiency as bioindicator for urban pollution. Also, Fosu-Mensah *et al.* (2017) evaluated the levels and risk of heavy metal contamination in soils and vegetation around the Korle Lagoon area in Accra where burning of e-waste and cultivation of vegetables takes place. High accumulations of heavy metals were observed in the plants samples collected, with the concentrations of Cu, Pb, Ni and Cd exceeding their acceptable limits. As it was also stated in the study of Ogundele *et al.* (2012), the results of the study that was conducted in Kastamonu indicate that heavy metal accumulation is seen more in plants which are near to the source of pollution, that is, the places where vehicle traffic is dense, and thus, the amounts of Cu, Pb and Ni were determined the highest in city center.

Furthermore, Dadea *et al.* (2016) and Ekmekyapar *et al.* (2012) state that Cu and Zn values are higher in the leaves of plants where traffic is dense, and that this can be an indication that these metals are in the air due to traffic. Within the scope of this study, it was determined that in the leaf samples of *Platycladus orientalis* in the city center where traffic is the densest, Pb, Cu and Zn values were determined to be higher when compared to other species. In this context, it is possible that Pb, Cu and Zn metals were in the air due to traffic density in the city center, and it was predicted that *Platycladus orientalis* could be used as a biomonitor for this situation.

Results of the study by Piczak *et al.* (2003) demonstrate that metal accumulation of birch, willow, lime and maple leaves have significant differences. It was determined that there is a significant difference in the Cu, Pb, Ni and Zn retention characteristic of 4 shrub species which was chosen within the scope of this study. Also, region have a statistically significant effect on the concentration distribution of four heavy metals.

The benefits (sound, scenery, noise screening, etc.) of roadside plantation in terms of decreasing the negative impacts that occur on roads were proven by the conducted studies (Forman, 2000; Perez *et al.*, 2016; Kollarou and Kollaros, 2014; Singh *et al.*, 2014). One of these benefits is that it helps decrease the usage of heavy metal concentration in the environment and fulfill the duty of screening.) Examining whether or not roadside plantation has an effect on the heavy metal accumulation in the agricultural lands in the sides of Trsihuli Highway which is between the cities of Trishuli and Kathmandu in Nepal, Zhang *et al.* (2012 stated that roadside plantation had an impact on decreasing the heavy metal concentrations in agricultural lands. The results of the study conducted in Kastamonu also supports the results of this study. Since roadside plants provide environmental utilizations to get less affected by heavy metals by retaining and thus screening the heavy metals that were oscillated to the air, using plants that have high levels of heavy metal retain characteristics in areas where the traffic is dense, has great importance for the increase of air quality.

Our studies in literature showed that so little is known about the biomonitoring by shrub species (Ataabandi *et al.*, 2010; Fernandez Espinoza and Rossini Oliva, 2005; Hoodaji *et al.*, 2012; Rosllsini Oliva and Mignorance, 2006) and effect of air pollution on shrubs. Ataabandi *et al.* (2010) stated that conifers were better than deciduous ones for airborne Fe and Ni contamination monitoring. In addition, according to the results of their study, it has been determined that Fe and Ni concentrations were more in Platycladus oreintalis leaves and Fe concentrations were more in Berberis vulgaris barks. Rezajenad (2009) tried to determine the effect of air pollution on the structures of plants especially in Platycladus orientalis. The observation results suggested that plants also Platycladus orientalis try to respond suitably by adjusting their metabolism so that minimum damage was done due to air pollutants. Also our study results showed that Platycladus orientalis is resistant to air pollution and can therefore be used as a biomonitor.

4. Conclusion

In the study which was conducted to determine the shrub species which can be used as the biomonitor of air pollution that originates especially from traffic and which could provide the opportunity to increase the air quality in urban areas, 4 shrub species which are mostly used for road plantation in Turkey was selected. Besides, 3 different areas with different human usage density were selected to demonstrate the effect of heavy metal sources caused by traffic on plants more clearly. Leaf samples were collected at the end of the growing season from plants that spent 1 growing season in the same region. In order to get accurate results from samples, the most attention was paid for sterilization during collection and analysis.

When the results of the study were evaluated, it was observed that the highest Cu and Pb values were determined in the leaves *Platycladus orientalis* that was taken from the city center, the highest Zn values were determined in the leaves of *Buxus sempervirens that was taken from the periphery,* and the highest Ni values were determined in the leaves of *Buxus sempervirens* that was taken from the city center. Furthermore, in the barks of *Berberis thunbergii, Buxus sempervirens* and *Platycladus orientalis* that were taken from the city center, Cu value was determined more when compared to the leaves. It was observed that in the chosen plant species, Cu and Zn accumulation was higher than other heavy metals. Therefore, *Berberis thunbergii, Buxus sempervirens, Juniperus horizontalis*, and *Platycladus orientalis* leaves and barks behaved as a good collector for analyzed metals especially Cu and Zn. According to the analysis results, it was determined that *Platycladus orientalis* had the highest Cu and Pb retention characteristic and *Buxus sempervirens* had the highest Ni and Zn retention characteristic. Results indicate that *Platycladus orientalis* can be used as a biomonitor for Cu and Pb and *Buxus sempervirens* can be used as a biomonitor for Ni and Zn.

According to the results of the research, the accumulation levels of 4 heavy metals (Cu, Pb, Zn, Ni) showed a statistically significant difference in 4 shrub species and in 3 areas with different usage density. The results obtained within the scope of the study revealed that planning and implementation should be made in different areas in accordance with the characteristics and the needs of that area in order to ensure sustainable ecological protection and management. In this context, for the successful protection and management of the urban ecology, the species should be preferred according to the heavy metal resources and the density of these resources, especially in roadside vegetation. The preference of four bush species which were selected within the scope of the study for road planting will reduce the amount of Cu and Zn in the air in Kastamonu and in similar cities, and thus the desired air quality will be achieved. Also, they can be used as the biomonitors of traffic-originated pollution. Since Cu, Pb, and Zn, traffic-originated heavy metals, were determined in higher levels in the leaves of *Platycladus orientalis* in the city center, it can be transcribed that air pollution is seen more in the city center than in any other study areas, and that *Platycladus orientalis* can be used as a biomonitor for traffic-originated air pollution according to study results. In addition, *Buxus sempervirens* can be suggested to be used in order to reduce the amount of Zn and Ni in the air.

Acknowledgement

This study is performed with KU-HIZDES/ 2015- 09 project results supported by Kastamonu University Coordinatorship of Scientific Research Projects.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by Kastamonu University Coordinatorship of Scientific Research Projects [grant number KU-HIZDES/2015-09].

References

Aboal J.R., Fernandez J.A. and Carballeira A. (2004). Oak leaves and pine needles as biomonitors of airborne trace elements pollution. *Environmental and Experimental Botany,* **51(3)**, 215–225.

Ataabadi M., Hoodaji M. and Najafi P. (2010), Heavy Metal Biomonitoring by Plants Grown in an Industrial Area of Isfahan Mabarakeh Steel Company. *Journal of Environmental Studies*, **35(53)**, 83–92.

Belkayalı N. and Güloğlu Y. (2019), Physical and social barriers for disabled urban park users: case study from Kastamonu, Turkey. *Forestist*, **69(1)**, 35–43. doi: 10.26650/forestist.2019.414498.

Belkayalı N. and Ayan E. (2018), Classification of urban green spaces and parks: the case of Kastamonu. *Research and Development on Social Sciences, Monographs and Studies of the Jagiellonian University, Institute of Public Affairs*, Dorczak R., Lenart-Gansiniec R., Ruggiero C. and Ali İcbay M. (Eds.), Krokow, pp. 395–404.

Brown G., Schebella M.F. and Weber D. (2014), Using participatory GIS to measure physical activity and urban park benefits, *Landscape and Urban Planning*, **121**, 34–44. https://doi.org/10.1016/j.landurbplan.2013.09.006.

Ceburnis D. and Steinnes E. (2000), Conifer needles as biomonitors of atmospheric heavy metal deposition: comparison with mosses and precipitation, role of the canopy. *Atmospheric Environment*, **34 (25)**, 4265–4271.

Chamber of Environmental Engineers. (2018), Chamber of Environmental Engineers Air Pollution Report 2017, [Internet]. Turkey; [cited 2018 June 1]. Available from: http://cmo.org.tr/resimler/ekler/2145efce8f89f52_ek.pdf.

Conti M.E. and Cecchetti G. (2001), Biological monitoring: lichens as bioindicators of air pollution assessment: a review, *Environmental Pollution*, **114**, 471–492, https://doi.org/10.1016/S0269-7491(00)00224-4.

Dadea C., Bacchiocchi S.C., Rocca N., Mimmo T., Russo A. and Zerbe S. (2016), Heavy metal accumulation in urban soils and deciduous trees in the City of Bolzano, N Italy. Waldökologie, Landschaftsforschung und Naturschutz – *Forest Ecology, Landscape Research and Nature Conservation*, **15**, 35–42.

Dam-o P. (2015), *Examination of some heavy metal pollution in roadside plants using X-Ray Spectroscopy*. University of Łódź Chair of Modelling Teaching Processes, Doctoral Dissertation, Poland, pp. 99.

Ekmekyapar F., Şabudak T. and Şeren G. (2012), Assessment of heavy metal contaminatıon in soil and wheat (Triticum aestivum L.) plant around the Çorlu–Çerkezkoy highway in thrace region. *Global NEST Journal*, **14(4)**, 496–504.

Fernandez Espinoza A.J. and Rossini Oliva S. (2005), The composition and relationships between trace element levels in inhalable atmospheric praticles (PM_{10}) and in leaves of; Nerium oleander L. and Lantana camara L. *Chemosphere*, **62(10)**, 1665–1672.

Forman R.T.T. (2000), Estimate of the area affected ecologically by the road system in the United States, *Conservation Biology,* **14(1)**, 31–35.

Fosu-Mensah B.Y., Addae E., Yirenya-Tawiah D. and Nyame F. (2017), Heavy metals concentration and distribution in soils and vegetation at Korle Lagoon area in Accra, Ghana. *Cogent Environmental Science,* **3**: 1405887, https://doi.org/10.1080/23311843.2017.1405887.

GDF. (2015), *Distribution of areas, wealth and increase to provinces. Turkey Forest Asset 2015*. Ministry of Forestry and Water Affairs, General Directorate of Forestry, [Internet]. Turkey; [cited 2018 June 10]. Available from: https:// www.ogm.gov.tr/ekutuphane/Yayinlar/T%C3%BCrkiye%20Orman%20Varl%C4%B1%C4%9F%C4%B1-2016-2017.pdf.

Hajar E.W.I., Sulaiman A.Z.B. and Sakinah A.M.M. (2014), Assessment of heavy metals tolerance in leaves, stems and flowers of Stevia rebaudiana plant. *Procedia Environmental Sciences.* **20(20)**, 386–393. doi: 10.1016/j.proenv.2014.03.049.

Karagulian F., Belis C.A., Dora C.F.C., Prüss-Ustün A.M., Bonjour S., Adair-Rohani H. and Amann M. (2015), Contributions to cities' ambient particulate matter (PM): A systematic review of local source contributions at global level, *Atmospheric Environment,* **120**, 475–483.

Kocić K., Spasić T., Urośević M.A. and Tomaśević M. (2014), Trees as natural barriers against heavy metal pollution and their role in the protection of cultural heritage. *Journal of Cultural Heritage*, **15,** 227–233.

Kollarou V. and Kollaros G. (2014), Management of roadside vegetation, road-island planting and slope cover. Proceedings of the 12th International Conference on Protection and Restoration of the Environment, Liakopoulos A., Kungolos A., Christodoulatos C., Koutsopsyros A. (Eds.), Skiathos Island, Greece, 29 June-3 July 2014, 647–652.

Levy D.B., Redente E.F. and Uphoff G.D. (1999), Evaluating the phytotoxicity of Pb - Zn tailings to big bluestem (Andropogon gerardii vitman) and switchgrass (Panicum virgatum L.). *Soil Science,* **164(6)**, 363–375.

Liang C., Fangc H.L., Zhanga T.L., Wanga X.X. and Liu Y.D. (2017), Heavy metal in leaves of twelve plant species from seven different areas in Shanghai, China. *Urban Forestry & Urban Greening,* **27**, 390–398.

Mandiwana K., Resane T., Panichev N. and Ngobeni P. (2006), The application of tree bark as bio-indicator for the assessment of Cr(VI) in air pollution. *Journal of Hazardous Materials*, **137(2)**, 1241–1245.

Ogundele D.T., Adio A.A. and Oludele O.E. (2015), Heavy metal concentrations in plants and soil along heavy traffic roads in North Central Nigeria, *Journal of Environmental & Analytical Toxicology*, **5**, 6. doi: 10.4172/2161-0525.1000334.

Opaluwa O.D., Aremu M.O., Ogbo L.O, Abiola K.A., Odiba I.E., Abubakar M.M. and Nweze N.O. (2012), Heavy metal concentrations in soils, plant leaves and crops grown around dump sites in Lafia Metropolis, Nasarawa State, Nigeria. *Advances in Applied Science Research*, **3(2)**,780–784.

Perez M.A., Tegebu F.N. and Steenbergen F. (2016). Roadside planting in Ethiopia: turning a problem into an opportunity, *Sustainability in Environment*, **1(2)**, 98–115.

Piczak K., Sniewicz A. and Zyrnicki W. (2003), Metal concentrations in deciduous tree leaves from urban areas in Poland. *Environmental Monitoring and Assessment*, **86**, 273–287.

Probst A., Liu H., Fanjul M., Liao B. and Hollande E. (2009), Response of Vicia faba L. to metal toxicity on mine tailing substrate: geochemical and morphological changes in leaf and root. *Environmental and Experimental Botany,* **66(2)**, 297–308.

Pugh R.E., Dick D.G. and Fredeen A.L. (2002), Heavy metal (Pb, Zn, Cd, Fe, and Cu) contents of plant foliage near the anvil range Lead/Zinc Mine, Faro, Yukon Territory, *Ecotoxicology and Environmental Safety*, **52**, 273–279. doi:10.1006/eesa.2002.2201.

Rahul J. and Jain M.K. (2016), Effect of heavy metals on some selected roadside plants and its morphological study: a review, *American-Eurasian Journal of Agricultural & Environmental Sciences*, **16(1)**, 146–158.

Rezanejad F. (2009), Air pollution effects on structure, proteins and flavonoids in pollen grains of Thuja orientalis L. (Cupressaceae), Grana, **48**, 205–212, doi: 10.1080/00173130902949417.

Richards D.R., Passy P. and Oh R.R. (2017), Impacts of population density and wealth on the quantity and structure of urban green space in tropical Southeast Asia. *Landscape and Urban Planning*, **157**, 553–560. doi: http://dx.doi.org/10.1016/j.landurbplan.2016.09.005.

Rossini Oliva S. and Mingorance M.D. (2006), Assesment of Airbone Heavy Metal Pollution by Aboveground Plants Parts, *Chemosphere*, **65(2)**, 177–182.

Sawidis T., Breuste J., Mitrovic M., Pavlovic P. and Tsigaridas K. (2011), Trees as bioindicator of heavy metal pollution in three European cities, *Environmental Pollution*, **159**, 3560–3570.

Singh R.R., Goyal N. and Kaur N. (2014), Importance of roadside vegetation. *International Journal of Progresses in Civil Engıneering (IJPCE)*, **1(1),** 2394–4684.

Sulaiman F.R. and Hamzah H.A. (2018), Heavy metals accumulation in suburban roadside plants of a tropical area (Jengka, Malaysia). *Ecological Processes,* **7**, 28. https://doi.org/10.1186/s13717-018-0139-3.

TSI. (2018), Turkish Statistical Institute Number of Motor Vehicles in Kastamonu Province. [Internet]. Turkey; [cited 2018 June 10]. Available from: https://biruni.tuik.gov.tr/medas/?kn=89&locale=tr.

Turer D., Maynard J.B. and Sansalone J.J. (2001), Heavy metal contamination in soils of urban highways: comparison between runoff and soil concentrations at Cincinnati Ohio, *Water, Air, & Soil Pollution*, **132**, 293–314.

Ugolini F., Tognetti R., Raschi A. and Bacci L. (2013), Quercus ilex L. as bioaccumulator for heavy metals in urban areas: Effectiveness of leaf washing with distilled water and considerations on the trees distance from traffic, *Urban Forestry & Urban Greening*, **12(4)**, 576–584.

Ummeh S. and Toshio K. (2017), Classification of urban parks and their regional characteristics in Dhaka City, *Bangladesh. Journal of Environmental Science and Engineering*, **6**, 41–54.

United Nations. (2018), Urban Population. United Nations Population Division. World Urbanization Prospects: 2014 Revision, [Internet]. USA; [cited 2018 June 09]. Available from: https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS.

Kastamonu Map and Coordinates. (2018), [Internet]. Turkey; [cited 2018 June 10]. Available from: http://dunya.arztalep.com/tr-TR/kastamonu/kastamonu-haritasi.aspx.

Yıldız T. (2013), Kastamonu Central District Analysis, North Anatolian Development Agency, [Internet]. Turkey; [cited 2018 June 10]. Available from: https://www.kuzka.gov.tr/Icerik/Dosya/www.kuzka.gov.tr_16_PO2G10AN_kastamonu_merkez_ilce_analizi.pdf.

Zhang F., Yan X., Zeng C., Zhang M., Shrestha S., Devkota L.P. and Yao T. (2012), Influence of traffic activity on heavy metal concentrations of roadside farmland soil in mountainous areas, *International Journal of Environmental Research and Public Health*, **9**, 1715–1731; doi:10.3390/ijerph9051715.