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Accumulation of heavy metal pollution caused by traffic in forest trees in the park of Kerey and Janibek Khans of the city of Nur-Sultan, Kazakhstan

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Abstract: Air quality in Nur-Sultan, the fast-growing new capital city of Kazakhstan, has been poorly investigated. This research was carried in Kerey and Janibek Khans Park in Nur-Sultan, the capital city of Kazakhstan, which is affected by "different traffic density" on the roads. Three different categories of contamination (*i*) high pollution (distance from the main road 10–15 m), (*ii*) moderate pollution (distance from the side road 15–30 m), and (*iii*) low pollution (distance from the source of contamination 30–80 m) at different levels resulting from urban transportation were examined. The aim of the study is to determine the pollution accumulation amounts of Ni, Cd, Pb, Cr, Li, Co, Fe, and Zn in five different tree species: Norway spruce (*Picea abies* /L./ H. Karst.), blue spruce (*Picea pungens* Engelm.), Scots pine (*Pinus sylvestris* L.,), Siberian larch (*Larix sibirica* Ledeb.), and silver birch (*Betula pendula* Roth). Significant differences in Ni, Cd, Pb, Cr, Li, Co, Fe, and Zn accumulation amounts were determined between three different parts of the park exposed to different levels of contamination. Approximately twice higher Ni, 2.3 times Cd, 3.3 times Pb, 2.7 times Co, 1.6 times Zn accumulation were determined in the area exposed to high pollution than in the parts of the park exposed to low pollution. Cd deposition in the area exposed to high contamination was higher in silver birch than in Scots pine and Norway spruce, while Cr and Co deposition values were higher in Norway spruce than in birch and Scots pine.

Keywords: anthropogenic emission; contamination; heavy metals; Norway spruce; Scots pine

It is known that the anthropogenic emissions of air pollutants and then precipitation with heavy metals lead to side effects on both chemical and biological processes in soils and on plants. Especially, larger areas in the northern hemisphere are contaminated by several heavy metals through industrial and traffic-induced atmospheric deposition (Steinnes, Friedland 2006). Vehicles are one of the primary sources of air pollution in cities. Many pollutants emerge due to vehicles (e.g. exhaust gases, car wheels) (Ugolini et al. 2013). Pollutants lead to the visual pollution on plants, they also cause a change and delay in physiological and metabolic events with their accumulation on different parts of plant. Sarkar et al. (1986) stated that exhaust gas pollution accelerates peroxidase and catalytic activities in large leaves of natural plants, and the distance from the road is closely related with the catalytic activities of plants. Amit et al. (2000) specified that the cuticle and epidermal

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structure of *Azadirachta indica* A. Juss. and *Polyalthia longifolia* (Sonn.) Thwaites leaves changed in areas that are closer to heavy traffic and epidermal cells were damaged severely. Jahan and Zafar Iqbal (1992) concluded that exhaust gases damaged anatomical and morphological structures at polluted city centres; therefore there is an important decrease in petiole length, leaflet area and length of *Taraxacum campylodes* G.E. Haglund, and a decrease in spongy parenchyma in *Ficus benghalensis* L. plant and epidermis in *Eucalyptus* sp. Bayçu et al. (1999) reported that the amount of chlorophyll decreases in needle leaves of two old *Cedrus libani* A. Rich. which are in a polluted region depending on the concentration of Pb and Cd when they are compared with the plant leaves in a control region, but increasing peroxidase activity was determined. Bayçu et al. (2003) found that the roadside pollution resulted in a decline of chlorophyll amount in biannual leaves of Norway spruce more evidently, but it resulted in an increase in their peroxidase activity, and there was not a decrease in annual ring width.

With increasing population and changing living standards, it is unavoidable that the pollution will increase in parallel with the constantly increasing number of cars. The main factor of this pollution is the consumption of oxygen and release of harmful substances to the environment. More than 100 harmful substances in gas, aerosol and particle form from motor vehicles are generally exhaust gases (65–80%), crankcase ventilation (20%), carburettor and elements of fuel system (5–10%) and fuel tank ventilation (5%) essentially from four main parts (Güler 2006). The most essential pollutants that are from the exhaust gases among the fuel additives are Pb, Cd, and Zn. Heavy metals are also released into the atmosphere from corrosion and abrasion of car tires (Cd and Zn) and brake lining and engine alloys (Cu and Ni) (Haşimoğlu et al. 2002). The addition of organic lead compounds tetramethyllead (TML-Pb $(CH_3)_4$) and tetraethyllead (TEL-Pb $(C_2H_5)_4$) to gasoline is responsible for 100% of lead pollution in the atmosphere (Yücel 1996; Öztürk 2004). Because 70–75% of lead is discharged from the exhaust in the form of soluble inorganic lead compounds easily and 1% of it is discharged as tetraalkyl lead without changes (Öztürk 2004). Cd that exerts a toxic effect on humans and animals even at very low values is released into the atmosphere from several sources. In traffic, especially tire wear (rubber material including 20–90 mg Cd/kg), oil, gasoline and fuel wastes including Cd from diesel oil are Cd sources (Özbek et al. 1993).

As mentioned previously, heavy metals play a dangerous role. While some heavy metals are beneficial to plants, Fe, Cu, Zn, Mn and Mo are essential for plant growth, Co and Ni stimulate plant growth, high concentrations of heavy metals have a toxic effect on both plants and other living things (Daghan et al. 2013). Therefore, monitoring heavy metal concentrations is extremely important. Along with the increasing population and vehicle density, traffic pollution is a potential and important problem for the city of Nur-Sultan. In this research, the main focus is to investigate the amounts of heavy metal pollution with Ni, Cd, Pb, Cr, Li, Co, Fe, and Zn in the tree species *Picea abies* (L.) H. Karst., *Picea pungens* Engelm., *Pinus sylvestris* L., *Larix sibirica* Ledeb. and *Betula pendula* Roth which are located in the Kerey and Janibek Khans Park of Nur-Sultan, the capital city of Kazakhstan.

MATERIAL AND METHODS

Material. The research was carried out in the Kerey and Janibek Khans Park located near the roads that have different traffic densities in the capital city of Nur-Sultan in Kazakhstan (Figures 1 and 2). Nur-Sultan is located in central Kazakhstan on the Ishim River in a very flat, semi-arid steppe region. The elevation of Nur-Sultan is 347 m a.s.l. The city is the second coldest national capital in the world. It has an extreme continental climate with warm summers and long, very cold, dry winters. January is the coldest month with an average temperature of –14.2 °C. Summer temperatures occasionally reach 35 °C while the temperatures of –30 to –35 °C are not unusual between mid-December and early March. Nur-Sultan has frequently high winds, the effects of which are felt particularly strongly on the fast-developing but relatively exposed left bank area of the city. The average annual temperature is 3.1 °C. There is 300 mm of precipitation per year (URL1 2021).

The park of Kerey and Janibek Khans (latitude: 51°09'59.5''N, longitude: 71°25'02.3''E) is situated in the newly configured part of the city and there are no factories near it. The prevailing wind direction is SW to NW. About 309 thousand vehicles are available in the city. It is examined for different levels of contamination: (*i*) high contamination – distance from the main road 10–15 m, (*ii*) mod-

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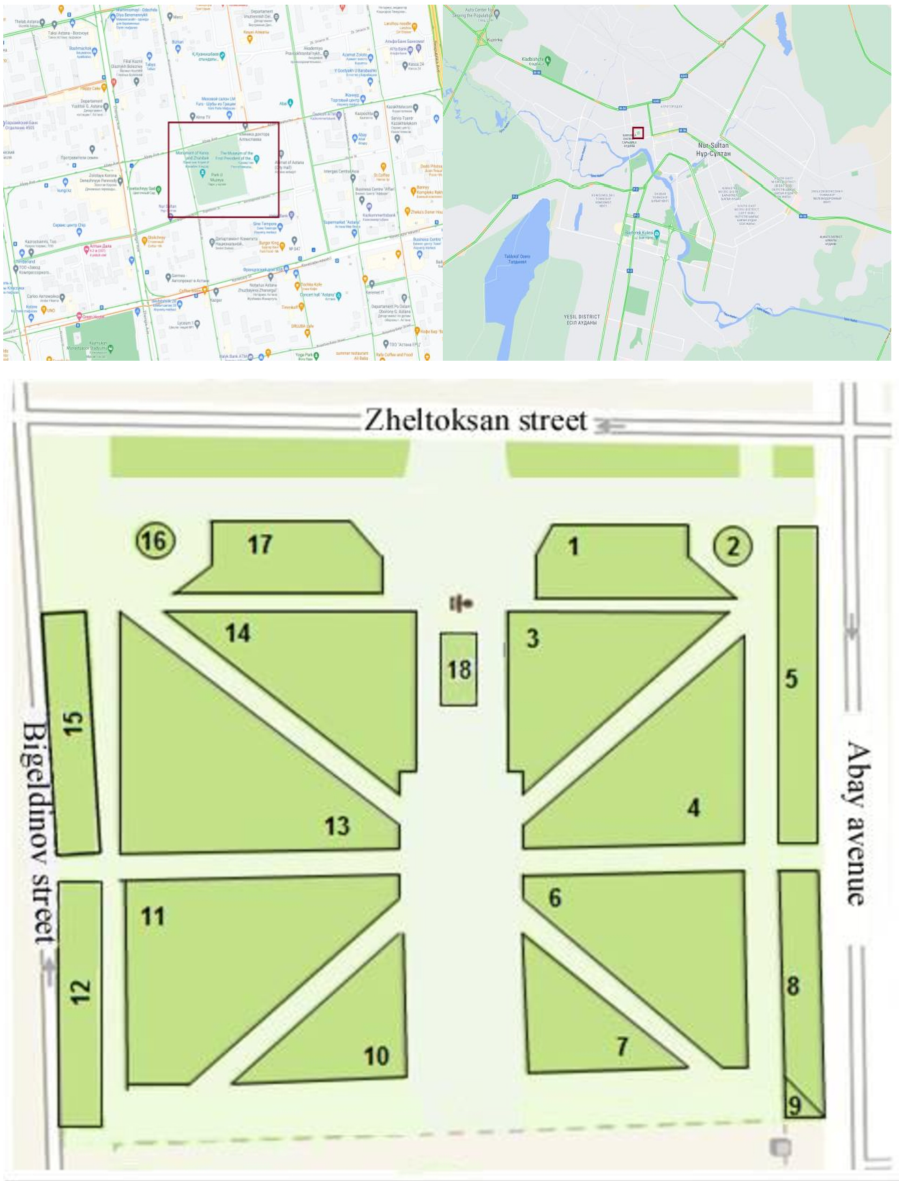

Figure 1. Location of Kerey and Janibek Khans Park in a city map and the location of parts of the Park according to main and secondary roads

erate contamination – distance from the roadside 15–30 m, and (*iii*) low contamination – distance from the contamination source 30–80 m that stems from several levels of vehicle traffic, in relation to *P. abies*, *P. pungens*, *P. sylvestris*, *L. sibirica* needles and *B. pendula* leaves (Table 1). Five repetitions of needle and leaf samples were taken from the middle and outer part of the tree crowns, and the direction facing Abay Avenue.

In this research, leaf and needle samples were used as research material. In many researches conducted in different regions and species it was stated that leaves are the convenient material to determine heavy metal accumulation (Bu-Olayan, Thomas 2002a, b; Olivares 2003).

Method. The leaf sampling was analysed from leaves (broadleaf and needle leaf) taken at the end of the vegetation period (November 2020). The samples brought to the Kastamonu University, Prof. Dr. M. Hakan, AKYILDIZ Central Laboratory for the analysis of Ni, Cd, Pb, Cr, Li, Co, Fe and Zn were grouped primarily according to the types of tree and exposure distance from the contamination. The washing and wiping procedure was not

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Figure 2. View of the Kerey and Janibek Khans Park

applied to leaf samples used for the research object. The labelled samples were dried until air-dried for 15 days. The samples that became air-dried were dried until fully dried in the oven at 45 °C. In the next stage, plant samples were ground, powdered and weighed as 0.5 g and put into tubes designed for MILESTONE branded (CEM, USA) MARS 6240-50 model microwave. 10 mL of 65% HNO_3 was added to the samples. Then, the prepared samples were burned in a microwave at a pressure of 280 PSI and temperature of 180 °C for 20 min. The tubes were taken out of the mi-

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Table 1. Tree species in parts of Kerey and Janibek Khans Park exposed to contamination at different levels

Exposure level of contamination	Part No.	Distance to road (m)	Species of tree
High	1	10–15 (main road)	*Picea abies*
	2		–
	3		*P. abies, Betula pendula*
	14		*Pinus sylvestris, P. abies, B. pendula*
	16		*B. pendula*
	17		*P sylvestris, Picea pungens, B. pendula*
	18		–
Moderate	4	15–30 (side road)	*P. abies, B. pendula, P. sylvestris, P. pungens*
	5		–
	6		*P. sylvestris, B. pendula*
	8		*Larix sibirica*
	9		*B. pendula*
	11		*P. sylvestris, P. pungens, B. pendula, P. abies*
	12		*B. pendula*
	13		*P. sylvestris, Picea abies, B. pendula*
	15		–
Light	7	30–80 (no road)	*P. sylvestris, P. pungens, P. abies*

crowave after the procedures were completed and left to cool. The tubes were filled to 50 mL by adding deionized water to the cooled samples. The prepared samples were filtered through the filter paper and then they were examined at appropriate wavelengths in the Spectroblue brand (AMETEK, Germany) Spectroblue II model ICP-OES device. The detection limits for heavy metals obtained from the ICP-OES device: Pb, 0.377 ppb; Cd, 0.063 ppb; Cr, 0.311 ppb; Ni, 0.171 ppb; Fe, 0,00068 ppm; and Zn is 0.00634 ppm.

Statistical evaluations. The analysis of variance was applied to each variable based on the distance from the source of contamination and type of tree factors on the 3-replicated data obtained by the ICP-OES analysis. The Newman-Keuls multiple test was applied to determine in what species the accumulation was higher in the processes where the difference was detected.

RESULTS AND DISCUSSION

While there was no significant difference in the accumulation values of Ni, Pb, Li, Fe and Zn between the trees of Norway spruce, silver birch and Scots pine in the area exposed to high pollution, a significant difference was found between the accumulation values of Cd and Cr. Cd accumulation was higher in silver birch than in Scots pine and Norway spruce, while Cr and Co accumulation values were higher in Norway spruce than in silver birch and Scots pine (Table 2). Ho and Tai (1988) emphasized that Cd, Pb, Cu, Zn, Fe and Mn values in roadside soil and grass of 36 regions in Hong Kong increased both in turf plants and soil and this increase was related with traffic density.

There was no difference between the species Norway spruce, silver birch, Scots pine and Siberian larch in Cr, Li, and Co accumulation values in the medium contamination area; on the other hand, there was a significant difference between these species in Ni, Cd, Pb, Fe and Zn accumulation amounts. While Ni, Cd and Pb accumulation was at the lowest level in Siberian larch and Fe accumulation was at the highest level in the birch trees (Table 2).

There were no statistically significant differences in the accumulation of all Ni, Cd, Pb, Cr, Li, Co, Fe and Zn elements in the birch trees, Norway spruce and Scots pine and blue spruce in the area exposed to the low contamination (Table 2). The significant differences were found between the three different categorized regions of the Park in accumulation amounts of Ni, Cd, Pb, Cr, Li, Co, Fe and Zn (Table 3, Figure 3). There was a nearly twice higher

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Table 2. The analysis of variance of the results of tree species in Kerey and Janibek Khans Park with different contamination intensity

Species	Ni	Cd	Pb	Cr	Li	Co	Fe	Zn
High pollution (ppb)								
Picea abies	1 531.25 ± 208	272.3 ± 19^{b}	3 402.8 ± 778	1 767.81 ± 241^{a}	2 919.51 ± 337	341.81 ± 34	274 951 ± 33 411	63 428.6 ± 9 511
Betula pendula	1 707.24 ± 90	328.1 ± 11^{a}	4 984.1 ± 486	1 158.17 ± 101^{b}	3 691.12 ± 717	410.77 ± 30	246 094 ± 29 076	83 154.5±10 205
Pinus sylvestris	1 823.97 ± 40	266.5 ± 9^{b}	3 092.1 ± 655	1 217.2 ± 89^{b}	3 721.60 ± 678	338.44 ± 31	246 043 ± 32 924	94 906.9 ± 19 590
F value	*F*: 1.00^{ns}	*F*: 6.10**	*F*: 2.69^{ns}	*F*: 4.38*	*F*: 0.51^{ns}	*F*: 1.69^{ns}	*F*: 0.27^{ns}	*F*: 1.46^{ns}
Moderate pollution (ppb)								
Picea abies	1 201.58 ± 271^{ab}	179.51 ± 39^{ab}	1 579.8 ± 237^{bc}	1 083.96 ± 96	1 858.47 ± 477	257.54 ± 38	251 012 ± 26 733^{ab}	41 319 ± 4 533^{ab}
Betula pendula	1 238.56 ± 91^{ab}	171.4 ± 28^{ab}	2 457.5 ± 253^{ab}	1 409.8 ± 184	1 869.47 ± 212	302.13 ± 28	411 059 ± 75 032^{a}	55 164 ± 7 348^{ab}
Pinus sylvestris	1 530.93 ± 113^{a}	249.7 ± 27^{a}	3 148.4 ± 327^{a}	875.27 ± 67	3 256.16 ± 645	315.32 ± 23	180 436 ± 11 016^{b}	65 861 ± 9 716^{a}
Larix sibirica	770.1 ± 225^{b}	114.36 ± 23^{b}	1 404.75 ± 493^{c}	1 097.16 ± 361	1 692.28 ± 140	251.75 ± 76	335 772 ± 125 470^{ab}	30 553 ± 5 886^{b}
F value	*F*: 1.73**	*F*: 1.92*	*F*: 6.35**	*F*: 2.04^{ns}	*F*: 2.48^{ns}	*F*: 0.66^{ns}	*F*: 2.91*	*F*: 3.13**
Light pollution (ppb)								
Picea abies	701.05 ± 60^{b}	117.11 ± 15^{ab}	1 311.75 ± 157^{b}	905.76 ± 75^{b}	1 534 ± 223^{bc}	134.68 ± 13^{b}	180 676 ± 8 233^{bc}	52 906.3 ± 17 010^{b}
Betula pendula	1 281 ± 176^{ab}	211.53 ± 20^{a}	1 773.3 ± 457^{ab}	947.43 ± 66^{b}	3 097.13 ± 113^{a}	146.63 ± 10^{a}	211 521 ± 37 738^{b}	67 321.8 ± 11 002^{b}
Pinus sylvestris	584.25 ± 15^{b}	53.05 ± 1.2^{b}	522.58 ± 10^{b}	562.15 ± 24^{b}	1 072.28 ± 52^{c}	106.66 ± 2^{b}	130 471 ± 4 110^{c}	21 971 ± 5 445^{b}
Picea pungens	2 060 ± 508^{a}	208.7 ± 62^{a}	2 946.26 ± 857^{a}	1 592.6 ± 236^{a}	2 064.1 ± 560^{b}	296.18 ± 39^{a}	317 059 ± 18 644^{a}	451 373 ± 59 009^{a}
F value	*F*: 6.20**	*F*: 5.07**	*F*: 4.23**	*F*: 11.1***	*F*: 7.98**	*F*: 17.1***	*F*: 13.3***	*F*: 4.18**

a, b, c – homogeneous groups; *P*-value: * 95% confidence level; **99% confidence level; ***99.9% confidence level; ns – non-significant

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level of Ni, 2.3 times Cd, 3.3 times Pb, 2.7 times Co, 1.6 times Zn accumulation was determined at very high contamination compared to the area exposed to lower contamination. Jaradad and Moman (1999) conducted their study on both sides of the great highway connecting Jordan's southern area with Amman; the heavy metal accumulation of Cu, Pb, Cd and Zn in plants and soil was conversely related with the distance from the road; soil and plants on the roadside had a high heavy metal content and these values indicate heavy metal contents that are parallel with the density of traffic and reached significant values in the urban space. Rodriguez-Flores and Rodrigez-Castellon (1982) stated that Pb and Cd elements were higher than the normal level as far as the distance of 33 m from the highway and decreased rapidly after this distance. The researchers assert that these heavy metals accumulate on curved areas more than on the roads that are flat, at the same time the wind is also effective on the distribution of contamination. Ndiokwere (1984) claimed that the amount of Cd, Cu, Cr, Ni, Pb, and Zn caused by vehicle emissions along the highway with high traffic density in Nigeria decreased as the distance from the road increased. Bayçu et al. (2003) emphasized that the accumulation of Pb and Cd amounts has a negative effect on the chlorophyll activity in response to stress in *P. abies* needles, it resulted in an increase in the activity of the enzyme peroxidase.

Erdem (2018) stated that different types of Pb concentrations vary significantly depending on the traffic density, whereas the average Pb concentration in areas where there is no traffic is 346 ppb, but it is 635 ppb in areas with low traffic and 1 782 ppb in high traffic areas. Pinar (2019) stated that Pb concentration increased with traffic density. In a study conducted by Smith (1971) on *Pinus strobus* L. trees, it was revealed that Pb contamination decreased regularly with the increasing distance from the highway. It is stated that Pb amounts are higher than 100 ppm in the samples obtained from the distance of 15 m to the road. In this study conducted by us, the accumulation was determined between 3 092.8 and 4 984.1 ppb in Scots pine, Norway spruce and birch at the distance of 10–15 m, among the three available species the birch was exposed to the highest Pb accumulation with large leaf surfaces. On the other hand, Şanda (1993) in his study on heavy metal accumulation in plants at the city centre and on peripheral roads of Konya investigated the accumulation of Pb in coniferous and broadleaf (*Fraxinus excelsior* L., *Platanus orientalis* L., *Aesculus hippocastanum* L., *Cedrus libani* A. Rich., and *Platycladus orientalis* L. Franco) woody species. It was stated that evergreen species accumulate more Pb when compared with deciduous woody species. Bingöl (1992) stated in his study investigating the accumulation of Pb in *Aesculus hippocastanum*, one of the Ankara street trees, that the accumulation in leaves is the highest due to the larger surface area and the direct gas exchange with the atmosphere compared to the other organs, followed by the rough surface of the shell tissue and the lowest accumulation is in the branches. Krishnayya and Bedi (1986) stated that the effect of Pb contamination on the pollen germination and production of seed of *Cassia tora* L. and *Cassia occidentalis* L. plants returned to the normal values nearly after a distance of 60 m.

Türkan (1986) found that the accumulation of Pb, Cd, and Zn increased also with the increasing traffic density and decreased with the increasing distance

Table 3. The results of the analysis of variance among the areas according to pollution severity based on *P. abies*, *B. pendula*, and *P. sylvestris*

Exposure level of contamination	Ni	Cd	Pb	Cr	Li	Co	Fe	Zn
High	1 677.76 ± 79[a]	294.13 ± 9.3[a]	3 984.1 ± 385[a]	1 376.14 ± 102[a]	3 441.6 ± 357[a]	369.7 ± 19[a]	296 210 ± 34 123[a]	79 517.3 ± 7 285[a]
Moderate	1 304.2 ± 102[b]	194.98 ± 19[b]	2 349.2 ± 177[b]	1 158.68 ± 87[a]	2 235.5 ± 259[b]	290.8 ± 18[b]	255 700 ± 18 029[a]	53 402 ± 4 346[b]
Light	855.43 ± 94[c]	127.23 ± 17[c]	1 202.5 ± 196[c]	805.11 ± 52[b]	1 901.1 ± 224[b]	162.6 ± 15[c]	174 223 ± 14 613[b]	49 399 ± 8 012[b]
F value	*F*: 12.7***	*F*: 19.7***	*F*: 19.3***	*F*: 6.44**	*F*: 6.22**	*F*: 20.5***	*F*: 3.30**	*F*: 7.05**

a, b, c – homogeneous groups; *P*-value: *95% confidence level; **99% confidence level; ***99.9% confidence level; ns – non-significant

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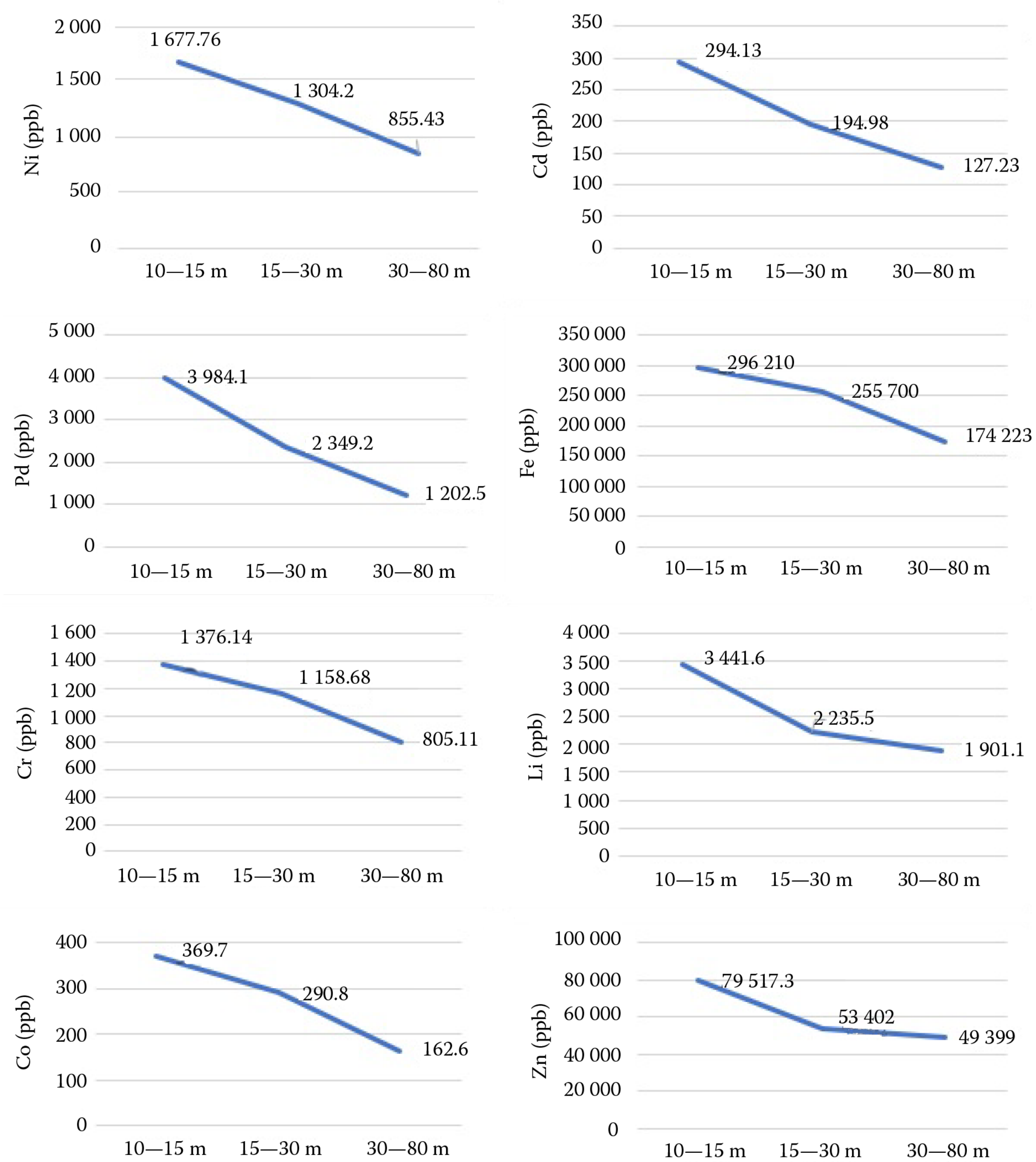

Figure 3. Changes in the amounts of Ni, Cd, Pb, Cr, Li, Co, Fe, and Zn elements according to the distance from the pollution source

from the road in grown and cultured plants along İzmir and surrounding roads: *Eucalyptus camaldulensis* Dehnh., *Morus alba* L., *Olea europaea* L. var. *sylvestris* (Miller) Lehr, *Pistacia terebinthus* L., *Quercus coccifera* L., *Vitex agnus-castus* L., *Phragmites australis* (Cav.) Trin. ex Steud., *Malva sylvestris* L., *Dittrichia graveolens* (L.) Greuter, *Thymus capitatus* (L.) Hoffmanns. & Link, *Marrubium vulgare* L., *Oryzopsis coerulescens* (Desf.) Hack., *Cucumis melo* L. and *Zea mays* L. plants. It was specified that the highest accumulation was in *Dittrichia graveolens*, *Morus alba, Oryzopsis coerulescens* and *Thymus capitatus* species. This was due to leaf hairiness.

In another study conducted by Elik and Akçay (2000), heavy metal contamination at Sivas city in terms of local and temporal variation showed that the accumulation values of Pb, Cd, Ni, Cr, Cu, Fe and Al elements in *Robinia pseudoacacia* L. shoots were 10–25%, when compared to the *P. sylvestris* species. This result is related with the activity of *R. pseudoacacia* species with rapid growth, low density of leaves and stickiness of the leaf surface.

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In a study monitoring the heavy metal contamination due to traffic carried out at Eskişehir, it was found that there was a positive correlation between the Pb values in *Populus nigra* subsp. *nigra* leaves and traffic densities, while the maximum Pb value was three times higher than the desired maximum value (Bereket, Yücel 1990). In the analysis of Caselles (1998) on *Citrus lemon* L. leaves, there was a relationship between the Pb concentration and the distance from the road; it was specified that the accumulation declined with the increasing distance from the road.

It has been emphasized that the heavy metal concentration in plants may vary considerably depending on the traffic density (Assirey et al. 2015; Lei et al. 2015) and on plant organelles (Emamverdian et al. 2015), and the developmental stage (Shahid et al. 2017) of the plant. As a result, the heavy metal concentration in plants is formed due to the interaction of many factors.

CONCLUSION

Expanding green areas, parks and urban forests is the most effective solutions among the suggestions for a healthier and more qualified life besides combating air pollution. In most studies conducted, it is a known fact that green areas and plants used in these areas decrease all types of air pollution in several ways. In contaminated areas due to the heavy metal accumulation, the factors of plant species, traffic density, topography and the distance of the microhabitat from the road are effective. In this investigation, it was found that Ni, Cd, Pb, Cr, Li, Co, Fe and Zn accumulation in the area represents high contamination. There is 1.6–3.3 times higher heavy metal accumulation compared to the low contamination area. Instead of TML-Pb and TEL-Pb, the ferrocene ($C_{10}H_{10}Fe$) use is more suitable, since it is a non-toxic material that is used for several purposes such as medicinal applications. Furthermore, to make detailed investigations for evaluating the effects of contamination on humans and other living things more accurately and to take the necessary precautions, it is important to make observations for a long-term period and monitoring. It would be of high environmental interest in urban areas to specify the changes in contamination accumulations during the year, determine the toxic boundaries in different tree species in the relevant ecology and make detailed and further research to specify contamination in soil and several agents of plant.

The results of the research are of national and international scientific importance due to the seriousness of the air pollution problem in the new and fast-growing capital of Nur-Sultan city of Kazakhstan and the lack of data and information in the region. In addition, necessary measures by taking the government to control or reduce atmospheric pollution in Nur-Sultan can lead to significant benefits to society in terms of reduced negative health impacts.

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