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Heavy Metals (Cd, Cu, Ni, Zn and Pb) Uptake by Various Components of Smooth-Leaved Elm (*Ulmus carpinifolia*) Tree in Abadeh City

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Abstract

The concentrations of cadmium, copper, nickel, zinc and lead were investigated in various components of smooth-leaved elm (*Ulmus carpinifolia*) tree in three sites (polluted, moderately polluted, and control) in Abadeh, Iran, in July 2015. The experiment was conducted using factorial experiment in a Completely Randomized Design with three replications. The concentration of heavy metals was measured in the mentioned indicator using atomic absorption spectroscopy method. The results showed that polluted and control sites had the highest and lowest Cd, Cu, Ni and Zn, respectively, indicating that vehicular traffic was the main source of these heavy metals. The moderate level of Pb concentration (0.15 mg l^{-1}) was observed in control site. The accumulation pattern of the studied elements was in the order of Ni=Zn>Cu>Cd>Pb. The concentrations of heavy metals were lower than the permitted limits except Cd in leaf, root and stem. Smooth-leaved elm (*U. carpinifolia*) tree can be used as a biomonitor of heavy metals pollution in Abadeh city.

Keywords: Biomonitor, Environmental pollutants, Traffic.

INTRODUCTION

Trees and shrubs are a valuable addition to most properties. Properly planted, well maintained trees add beauty, wind protection, shade, wildlife habitat, visual screening, and other benefits to the landscape (Kuhns and Rupp, 2000). *Ulmus* species have been widely used as shade and ornamental trees (White and Klingeman, 2014). Elms are deciduous medium-sized trees, characterized by pollination and seed dispersal driven by the wind (Caudullo and de Rigo, 2016). Heavy metal pollution is an important environmental problem that can affect human health (Kojima, 2001). Heavy metals are released by industrial activities, agricultural activities, combustion of fossil fuels and automobiles and pollute air, soils, and waters (Mollov and Valkanova, 2009; Bargagli, 1998).

Among heavy metals, cadmium and lead are especially important due to their high toxicity and long half-life in humans and other animals. Lead is emitted into the urban environment largely by the leaded gasoline. In recent years, its emission into the urban environment has declined, due to the removal of lead from gasoline (Sarkar, 2002).

Many studies have used trees for monitoring elemental deposition from the atmosphere. Zare *et al.* (2016) used the leaves of cypress tree for monitoring the distribution of heavy metals Zn, Ni and Cu in the atmosphere of Isfahan. They showed that the concentration of heavy metals in descending order was as Zn>Cu>Ni. A higher accumulation of heavy metals was found in leaves compared to roots in all studied locations. Miri *et al*. (2016) revealed that the leaf and bark of U. carpinifolia can be used as bio-indicators of heavy metal pollution in the ambient air and the ecological risk imposed by them. Mansour (2014) demonstrated that heavy traffic sites had high heavy metal concentrations. The highest concentrations of heavy metals were related to zinc and lead. The mean metal concentration values in the leaf and bark were in the order of Cd<Cu<Pb<Zn and Cd<Pb<Cu<Zn, respectively.

Gholami *et al.* (2012) reported that emissions from automobiles and anthropogenic activities changed the concentration of heavy metal in the surrounding atmosphere of studied areas. The main source of heavy metal contamination belonged to motor vehicle traffic intensity. Sawidis *et al.* (2011) showed the higher amounts of trace metals in pine tree bark than in plane tree bark, implying its higher efficiency as bioindicator for urban pollution. Both indicator species were suitable as bioindicator of urban air pollution.

The aim of the present study was to determine the cadmium, copper, nickel, zinc, and lead concentrations in leaf, root, stem, and soil of smooth-leaved elm (*U. carpinifolia*) tree in the atmosphere of Abadeh city.

MATERIALS AND METHODS

The study was conducted by sampling smooth-leaved elm (*Ulmus carpinifolia*) tree in Abadeh (Lat. 31°08' N, Long. 52°40' E, Alt. 1570 m) in July 2015. According to the meteorological station of Abadeh, the average annual precipitation is 136.51 mm/y, minimum temperature is 2.24°C in January, and maximum temperature is 28.6°C in July. The relative humidity during daytime is relatively high ranging from 23.26% in August to 46.25% in April. The leaf, root, stem, and soil samples were collected from high-traffic (Basij St.), moderate-traffic (Esteghlal St.) and control sites (Rezvan St.) in summer after a rainless period.

The samples were taken from the trees considering the main wind direction (i.e. the highest wind speed). Leaves were collected from one species of *U. carpinifolia* trees to avoid the differences in dust absorption. At each site, three trees were selected randomly and the leaves were collected from four sides of the tree at two-meter high. For each tree, one soil sample was taken at 0-25 cm (root zone) from the experimental sites. The total number of collected samples was 36, distributed as 12 samples from high-traffic, moderate-traffic and control site. The samples were packed in clean cellulose bags separately, were labeled, and were taken to the laboratory on the same day.

All plant parts (leaves, stems and roots) were rinsed with distilled water three times to remove surface contamination, oven dried at 75°C for 48 h (to a constant weight, and the dry weight was recorded before grinding), and were then passed through a 2-mm sieve before analysis (Uba *et al.*, 2009). Approximately, 0.5 g of resulting samples was digested with 4 ml of H_2SO_4: 13 mL H_2O_2 in a closed Digesdahl system (Hach Co., USA) at 440°C to obtain a total extraction of heavy metals. The samples were filtered and diluted with deionized water to 50 ml (Brainina *et al.*, 2004; Unterbrunner *et al.*, 2006). The total concentrations of Cd, Cu, Ni, Zn and Pb were determined by atomic absorption spectroscopy using the Spectra (AA 220FS Varian).

The study was carried out as a factorial experiment based on a Completely Randomized Design with three replications. Analysis of variance (ANOVA) was performed using SAS (2001) software package. We applied Duncan's Multiple Range Test at P<0.05 for means comparison, when the F values were significant. In addition, MS-Excel 2007 software package was used for the drawing of charts. The phenotypic correlation between variable *x* and *y* (r_{xy}) was performed in SAS (2001) and it was estimated using Kwon and Torrie (1964) formula:

$$r_{xy} = \frac{Cov_{xy}}{\sqrt{(Var_x \, . \, Var_y)}}$$

where, Cov_{xy} is covariance between variable *x* and *y*, Var_x is variance of *x*, and Var_y is variance of *y*.

RESULTS AND DISCUSSION

Results of analysis of variance (ANOVA) are shown in Table 1. Simple effects were statistically significant at P<0.01, indicating differences in heavy metal concentrations in leaf, root, stem, and soil. The highest amounts of Cd, Cu, Ni, and Pb concentrations were related to soil (0.37, 0.40, 0.52, and 0.21 ppm, respectively), and the lowest amounts of Cd, Cu, and Ni concentrations were found in stem (0.09, 0.31, and 0.25 ppm, respectively) (Table 2).

Table 1. Analysis of variance (ANOVA) of the traits in elm tree on July 2015.

S.o.V	df	Mean squares (MS)				
		Cd	Cu	Ni	Zn	Pb
Sample	3	0.135 **	0.012 **	0.154 **	0.139 **	0.014 **
Site	2	0.161 **	0.099 **	0.009 **	0.08 **	0.034 **
Sample × Site	6	0.039 **	0.064 **	0.029 **	0.092 **	0.015 **
Error	24	0.00005	0.0001	0.00001	0.00002	0.00003
CV (%)		3.58	2.82	0.84	1.17	3.66

ns and **: Not significant and significant at the 1% levels of probability, respectively.

Table 2. Heavy metal contents of four various components collected from different sites.

	Treatment	Cd (mg l^{-1})	Cu (mg l^{-1})	Ni (mg l^{-1})	Zn (mg l^{-1})	Pb (mg l^{-1})
Sample	Root	0.13 c	0.37 b	0.42 b	0.33 c	0.17 b
	Stem	0.09 d	0.31 d	0.25 d	0.51 a	0.13 c
	Leaf	0.19 b	0.34 c	0.26 c	0.21 d	0.12 d
	Soil	0.37 a	0.40 a	0.52 a	0.39 b	0.21 a
Site	Rezvan (Control)	0.07 c	0.25 c	0.34 b	0.26 c	0.15 b
	Esteghlal (Moderate traffic)	0.22 b	0.39 b	0.35 b	0.39 b	0.22 a
	Basij (Heavy traffic)	0.30 a	0.43 a	0.39 a	0.43 a	0.11 b

*Means in each column followed by similar letter(s) are not significantly different at 5% probability level, using Duncan's Multiple Range Test.

Table 3. Heavy metal contents of four various samples collected from different sites in Abadeh city.

Treatment		Cd (mg l^{-1})	Cu (mg l^{-1})	Ni (mg l^{-1})	Zn (mg l^{-1})	Pb (mg l^{-1})
Sample×Site interaction	$Sa_1 \times S_1$	0.01 ^{i}	0.15 ^{i}	0.54 ^{b}	0.26 ^{h}	0.16 ^{g}
	$Sa_1 \times S_2$	0.24 ^{d}	0.35 ^{f}	0.34 ^{f}	0.23 ^{i}	0.21 ^{d}
	$Sa_1 \times S_3$	0.15 ^{f}	0.59 ^{a}	0.37 ^{d}	0.50 ^{b}	0.13 ^{h}
	$Sa_2 \times S_1$	0.01 ^{i}	0.37 ^{e}	0.23 ^{j}	0.23 ^{i}	0.10 ^{j}
	$Sa_2 \times S_2$	0.11 ^{h}	0.41 ^{d}	0.24 ^{i}	0.82 ^{a}	0.29 ^{a}
	$Sa_2 \times S_3$	0.18 ^{e}	0.17 ^{h}	0.27 ^{h}	0.48 ^{c}	0.01 ^{l}
	$Sa_3 \times S_1$	0.18 ^{e}	0.24 ^{g}	0.12 ^{k}	0.22 ^{j}	0.11 ^{i}
	$Sa_3 \times S_2$	0.13 ^{g}	0.36 ^{ef}	0.32 ^{g}	0.1 ^{k}	0.19 ^{e}
	$Sa_3 \times S_3$	0.27 ^{c}	0.43 ^{c}	0.35 ^{e}	0.31 ^{g}	0.07 ^{k}
	$Sa_4 \times S_1$	0.10 ^{h}	0.23 ^{g}	0.54 ^{b}	0.34 ^{f}	0.22 ^{c}
	$Sa_4 \times S_2$	0.41 ^{b}	0.43 ^{c}	0.46 ^{c}	0.39 ^{e}	0.18 ^{f}
	$Sa_4 \times S_3$	0.61 ^{a}	0.53 ^{b}	0.57 ^{a}	0.43 ^{d}	0.24 ^{b}

*Means in each column, followed by similar letter(s) are not significantly different at 5% probability level, using Duncan's Multiple Range Test.

S_1: Rezvan St. (Control), S_2: Esteghlal St. (Moderate traffic), S_3: Basij St. (Heavy traffic), Sa_1: Root, Sa_2: Stem, Sa_3: Leaf, Sa_4: Soil.

On the other hand, stem had the highest amount of Zn concentration (0.51 ppm) and leaf had the lowest amounts of Zn and Pb concentrations (0.21 and 0.12 ppm, respectively) (Table 2). The results revealed that the trend of mean heavy metal concentrations at the studied sites follows the order of soil>root>stem>leaf. The same results were reported for Pb (Satpathy and Reddy, 2013), Ni (Li *et al.,* 2010) and Cu (Oliva and Mingorance, 2006).

There were significant differences between sites for the studied traits, indicating the presence of different concentrations (mg l^{-1}) of heavy metals in various sites (Table 1). The heavy metals Cd, Cu, Ni, and Zn were found at high concentrations in high-traffic site (Basij St.), whereas moderate-traffic site (Esteghlal St.) contained high concentration of Pb (0.22 ppm) (Table 2). On the other hand, control site (Rezvan St.) had the lowest concentrations of Cd, Cu, and Zn (0.07, 0.25, and 0.26 ppm, respectively), whereas moderate-traffic (Esteghlal St.) and control (Rezvan St.) sites had the lowest concentrations of Ni (0.34 and 0.35 ppm, respectively) (Table 2). The mean metal concentration values were found to be in the order of Ni=Zn>Cu>Cd>Pb.

These findings were in accordance with those of Saba *et al*. (2015) and Ejidike and Onianwa (2015) who reported that Cu concentration in plant was higher than Cd. Kozanecka *et al.* (2002) also indicated that the mean metal concentrations were in the order of Zn>Cu>Pb.

Sample×site interactions were highly significant for all studied traits indicating the significant differences in Ni, Zn, Cu, Cd, and Pb concentrations in all samples collected from different sites (Table 1). $Sa_4 \times S_3$ interaction resulted in the highest concentration of Cd (0.64 ppm) and $Sa_1 \times S_1$ and $Sa_2 \times S_1$ interactions exhibited the lowest concentrations of Cd (0.01 ppm) (Table 3). The highest and lowest concentrations of Cu were related to $Sa_1 \times S_3$ and $Sa_1 \times S_1$ interactions (0.59 and 0.15 ppm, respectively). $Sa_4 \times S_3$ and $Sa_3 \times S_1$ interactions had the highest and lowest concentrations of Ni (0.57 and 0.12 ppm, respectively) (Table 3). The highest and lowest concentrations of Zn were related to $Sa_2 \times S_2$ and $Sa_3 \times S_2$ interactions (0.82 and 0.1 ppm, respectively). $Sa_2 \times S_2$ and $Sa_2 \times S_3$ interactions had the highest concentrations of Pb (0.29 and 0.01 ppm, respectively) (Table 3).

The results of correlation coefficient showed significant relationship between most studied traits (Table 4). The highest correlation coefficients between traits were related to Cu vs. Cd, Cd vs. Ni, and Pb vs. Ni (r = 0.60, r = 0.47 and r = 0.47, respectively), indicating that the origin of heavy metals in the investigated area was associated with high-traffic, industrial activities, structure of the soil and street dust emission. Significant correlation was found between Cu vs. Zn and Pb (r = 0.38 and r = 0.41, respectively). A positive correlation occurred between Zn vs. Pb (r = 0.38). The correlation coefficient between Pb vs. Cd was not significant because of low Pb concentration. Kord *et al*. (2010) also reported significant correlation between Ni vs. Cu and Pb vs. Zn, Ni and

Table 4. Correlation coefficients of heavy metal concentration.

Trait	Cd	Cu	Ni	Zn	Pb
Cd	-				
Cu	0.60 **	-			
Ni	0.47 **	0.23 ns	-		
Zn	0.22 ns	0.38 *	-0.01 ns	-	
Pb	0.31 ns	0.41 *	0.47 **	0.38 *	-

ns, * and **: Not significant, significant at the 5% and 1% levels of probability, respectively.

Cu in all studied sampling sites.

Heavy metals have the largest availability in soil and aquatic ecosystems and to a relatively smaller proportion in atmosphere as particulate or vapors (Nagajyoti *et al.*, 2010). The presence of heavy metals may vary from site to site, depending upon the source of individual pollutant (Lone *et al*., 2008).

Cadmium is not yet known to have any biological functions. On the contrary, it is said to be highly toxic to plants and animals. Compared with the other metals, cadmium is more mobile in soil in relation to both leaching and availability to plants (Ahmad and Erum, 2010). Soils containing high levels of Cd show visible symptoms of injury reflected in chlorosis, growth inhibition, browning of root tips and finally death in plants (Wójcik and Tukiendorf 2004; Mohanpuria *et al.*, 2007). The permissible limit of cadmium in plants, recommended by WHO, is 0.02 ppm (Nazir *et al.*, 2015). In the present study, the accumulation of Cd was found to be higher in leaves than in stem and roots, which was higher than the permissible limits (Table 2). The major natural sources for Cd emission to air are volcanoes, airborne soil particles, sea spray, biogenic material, and forest fires (Lichtfouse *et al.*, 2013). The regulatory limit of cadmium (Cd) in agricultural soil is 100 ppm soil (Salt *et al.*, 1995). The main anthropogenic input of Cd to soils occurs by industrial waste from processes such as electroplating, manufacturing of plastics, mining, paint pigments, alloy preparation, and batteries that contain Cd, composts, or fertilizers (Moradi *et al*., 2005). In addition, vehicle wheels, mineral oils and usage of waste mud may introduce cadmium into the soil and this increases Cd levels in plants (Günes *et al.,* 2004; Viard *et al.*, 2004). Nazir *et al*. (2015) reported similar results for Cd.

Copper is an essential element for plant growth, but causes toxic effects when shoots or leaves accumulate Cu levels exceeding 20 ppm (Borkert *et al.*, 1998). In all collected samples, the concentration of copper was recorded below the permissible limit. Plants absorb Cu from the soil most often through the roots (Oliva and Mingorance, 2006). The main sources of Cu in soil were probably the corrosion of vehicle tires, the power fuel burning, road traffic (Davami and Gholami, 2012), home tools production, metal manipulation, and ashes (Aksoy *et al*., 2005). Cu concentrations in roots were higher than those in shoots, which could be associated with its increased mobility from soil to roots indicating the affinity of roots to accumulate good amount of Cu and transferring a little to above ground plant parts. These findings were in agreement with Satpathy and Reddy (2013).

Nickel has been considered to be an essential trace element for human and animal health (Hassan *et al.*, 2012). Nickel is generally distributed uniformly across the soil profile but typically accumulates on the surface from deposition by industrial and agricultural activities (Haber *et al.,* 2000). Natural sources of atmospheric nickel levels include wind-blown dust, derived from the weathering of rocks and soils, volcanic emissions, forest fires, and vegetation (Cempel and Nikel, 2006). The highest concentrations of nickel are attributed to emissions from motor-vehicle that use nickel gasoline and by abrasion and corrosion of nickel from vehicle parts (Al-Shayeb and Seaward, 2001). According to the WHO report, the permissible limit of nickel in plants is 10 ppm. The results showed that Ni concentration in studied samples was less than the permissible limit.

The main sources of the pollutant Ni in the atmosphere were likely to be automobile parts corrosion and industry activities.

Zinc is an essential element in all organisms having an important role in biosynthesis (Kabata-Pendias and Pendias, 2001). Zinc plays a vital role in the physiological and metabolic process of many organisms. Nevertheless, higher concentrations of zinc can be toxic to the organism (Nazir *et al.,* 2015). The WHO's recommended limit of zinc in plants is 50 ppm (Shah *et al.*, 2013; Yilmaz and Zengin, 2004). In the present study, Zn concentrations were smaller than the normal limits. Therefore, it can be supposed that all three studied sites were unpolluted with Zn. The vehicular traffic has been a major source of Zn contamination at the studied sites. It could be attributed to emissions from motor vehicles that use nickel gasoline and to the abrasion and corrosion of nickel from vehicle parts (Hassan and Basahi, 2013).

Lead (Pb) is one of the most abundant toxic elements in soil that can adversely affect morphology, growth, and photosynthetic processes of plants (Nagajyoti *et al*., 2010). It is known as immobile element, which have a very low translocation from soil to leaves (de Nicola *et al*., 2003). Therefore, Pb tends to accumulate in the roots and is scarcely translocate into above ground organs (Kabata-Pendias and Pendias, 2001). Pb concentrations in vegetation grown in industrial and urban areas have increased in recent decades owing to human activities and road traffic (Mansour, 2014). In this study, the level of Pb was moderate at the control site, indicating that vehicle traffic is a minor emission source for Pb and that another Pb source (such as industrial activities) around the site could be blamed. Allen (1989) considered that the normal content of Pb in plants is less than 3 ppm. The results of this study for all the sites did not reveal high levels of pollution by Pb since concentrations in studied samples did not exceed the permissible limit.

CONCLUSION

The present study showed the heavy metal accumulation in different samples of *U. carpinifolia*. The ranking order of mean heavy metal concentrations at the studied sites was in the order of soil>root>stem>leaf which could be associated with high concentration of heavy metals in soil than in air. The highest correlation coefficients among the traits belonged to Cu vs. Cd, Cd vs. Ni, and Pb vs. Ni, indicating that heavy traffic, industrial activities, soil structure, and street dust emission could be found as origin of studied heavy metals. The highest and lowest Ni, Zn, Cu, and Cd concentrations were found in the defined high-traffic and control sites, respectively. This indicates that the vehicular traffic has been a major source of these heavy metal contaminations at the sites. The pattern of mean metal concentrations in the samples was in the order of Ni=Zn>Cu>Cd>Pb. The control site had moderate level of Pb, indicating that vehicle traffic was less important source of this element than other Pb sources (such as industrial activities) around the sites. The concentrations of Cu, Ni, Zn, and Pb in the samples were lower than the permissible limits set by the WHO, whilst, Cd concentration in leaf, root and stem exceeded the permissible limit. *U. carpinifolia* can be used as a simple way to monitor polluted sites in Abadeh city.

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