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Heavy Metals in Urban Roadside Plants from Amman, Jordan

K. M. Swaileh, M. Matani, R. M. Hussein

Department of Biology and Biochemistry, Birzeit University, Post Office Box 14, Birzeit, West Bank, Palestinian Authority

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Heavy metals are released into the environment by natural processess as well as human activities. The latter is the most important and diverse source of heavy metals especially in large cities where inhabitants, heavy traffic and and industrial activities are concentrated. The awareness and concern about the health risks from heavy metals has risen sharply over the last decades (Komarnicki, 2005). The etiology of a number of diseases, especially cardiovascular, kidney and nervous as well as bone diseases, is linked to the excessive contents of toxic metals in the human environment (Friberg et al, 1986). Lead is the most common example of anthropogenic environmental metal pollution. A part from industry, the emission of Pb was/is associated for several decades with the use of lead compound as anti-knock agents in gasoline (Komarnicki, 2005). Its toxic effect is primarily the inactivation of proteins (including enzymes) via the binding to sulfhydyl groups (Ewers and Schlipköter, 1984). This makes continuous monitoring and assessment of human environments of great importance. For this purpose, different biological indicators have been developed and utilized to detect pollution sources, deposition and distribution patterns and accumulation patterns. Plants are among the most studied bioindicators as they are usually found in urban, industrial and rural regions; can easily be identified, collected and cultured. In additions, metal levels in plant tissues reflect environmental concentrations of these metals.

In Jordan, the number of vehicles mostly operating by leaded fuel has increased rapidly during the last few years (Jaradat and Momani, 1999). Traffic congestions are becoming very common in the capital, Amman, especially in summer, inspite of the accelerating efforts made by the Kingdom to build more and more tunnels and bridges to solve the problem. This leads to increasing the concentrations of traffic pollutants, including metals. Although studies on traffic metal pollution started early in the developed countries, very few studies have been carried out in developing coutries, like Jordan, where data on pollutant metal concentration and distribution are extremely scarce and if present, then in the form of internal reports (Jaradat and Momani, 1999; Momani et al. 2000). The present study aims at investigating heavy metals (Pb and Cu) in tissues of five common urban roadside plants from different locations within the capital of Jordan, Amman. These plants were Aleppo pine (*Pinus halepensis*), oleander (*Nerium oleander*),

Correspondence to: K. M. Swaileh

cypress (*Cupressus sempervirens*), olive (*Olea europea*) and carob (*Ceratonia siliqua*).

MATERIALS AND METHODS

Leaves of five common rodside plant species were collected in June 2005 from different roadside locations within the Jordanian capital Amman. Samples were collected in triplicates from each location, put in plastic bags and transferred back to the Laboratory. Leaves were washed with deionized, double distilled water and dried at room temperature. Thereafter, leaves were ground to powder using a grinder with stainless steel knife, then stored in clean glass vials for later analysis. Some plant leaves were left without washing in order to estimate the amount of metals adsorbed externally to the surface of leaves.

Sub-samples (about 0.4 g plant powder) were digested in a mixture of 1:1 nitric: perchloric acids (Suprapur, Merck) (Swaileh et al., 2004). At the end of digestion, volumes were adjusted to 25 ml using double distilled water. Blanks and reference material (Hay Powder, IAEA/V-10) were run with the samples. Finally, concentrations of Pb and Cu were measured by a graphite furness atomic absorption spectrophotometer (Perkin-Elmer, AAnalyst 600). All accepted recoveries were within the 95% confidence interval of the certified values shown in Table 1.

Table 1. Mean certified metal concentration and 95% confidence interval of heavy metals in the reference material (Hay powder) provided by the IAEA, Austria.

Metal	Mean Concentration ($\mu g \cdot g^{-1}$ dry weight)	95% confidence interval of the mean ($\mu g \cdot g^{-1}$)
Pb	1.6	0.8-1.9
Cu	9.4	8.8-9.7
Zn	24	21-27

Statistical analysis of data was done using SYSTAT 11 for Windows Software (SYSTAT Software, inc. 2004). Before applying analysis of variance (ANOVA) test, data were tested for normality using Kruskal-Wallis normality test. Thereafter, statistical differences were tested using ANOVA or two-sample t-test. Following ANOVA test, Tukey HSD multiple comparison test was applied. Differences were considered significant at p values ≤ 0.05.

RESULTS AND DISCUSSION

Plants exhibited different abilities to concentrate the three metals. Cypress leaves were found to contain significantly higher Pb than pine leaves (Table 2). Whereas all other pairwise comparisons were not statistically significant. Oleander leaves were found to have significantly more Cu than carob and pine and more Zn than carob, olive and pine.

Table 2. Mean concentrations (μg g^{-1} dry weight ±SE) of metals in urban roadside plants collected from Amman, Jordan in July 2005.

Plant	Pb	Cu	Zn
Carob (*Ceratonia siliqua*)	3.11±0.32^{ab}	3.89±0.45^{b}	13.22±0.61^{b}
Cypress (*Cupressus sempervirens*)	3.44±0.28^{a}	4.72±0.38^{ab}	13.44±0.39^{ab}
Oleander (*Nerium oleander*)	2.66±0.30^{ab}	6.34±0.75^{a}	15.53±0.69^{a}
Olive (*Olea europea*)	2.66±0.35^{ab}	5.52±0.44^{ab}	12.83±0.49^{b}
Pine (*Pinus halepensis*)	2.14±0.18^{b}	4.02±0.29^{b}	13.27±0.47^{b}
p-value	0.031	0.003	0.008

Values denoted by different letters are significantly different from each other, n=12.

According to their levels in different plants, metals were having the following order Zn>Cu>Pb. The same order exists for the three metals in other plants from other regions (Table 3). Results of the present study are either comparable of less than those reported from other countries. Oleander leaves contained the highest levels if Cu and Zn. This plant is a common roadside plant in the Mediterranean countries. Therefore, it was suggeted as a biomonitor for metal contamination in urban environments in the Mediterranean region (Aksoy and Öztürk, 1997). Cypress was found to be the richest in Pb which indicates the possibility of using this plant as an indicator of metal contamination in urban environments. Levels of the three metals in all plant leaves studied were well below the phytotoxic range of metals in plant leaves defined by as 30-300, 20-100, and 100-400 μg g^{-1} for Pb, Cu, and Zn, respectively.

Table 3. Levels of metals (μg g^{-1} dry weight)in plants samples from the present study compared to other studies worldwide.

Country	Cu	Pb	Zn	Reference
Jordan	2-10	1-5	11-19	This study
West Bank	4-23	0.2-18	14-110	Swaileh et al (2004)
Turkey	3-6	3-28	8-21	Aksoy & Öztürk (1997)
Bulgaria	5-9	3-6	22-190	Djingova et al (1999)
Italy	2-38	4-50	11-60	Alaimo et al (2000)

Jaradat and Momani (1999) studied the concentrations of metals along a highway that connects the capital with the southern parts of Jordan. The mean concentrations of metals obtained ranged between 1-7, 10-31, and 15-98 μg g^{-1} for Pb, Cu, and Zn respectively. These levels are clearly higher than those obtained in the present study. Their results were obtained by analysing a single plant species, *Anabasis articulata*.

Metals from automobiles reach the environment mainly through atmospheric fallout. In order to investigate the importance of atmospheric fallout of metals and compare it with metals that are incorporated in plant tissues, some plant leaves (pine & oleander) were analysed without being washed (Table 4). The results show that washing plant leaves removes significant amounts of metals that are deposited on the leaf surface. Of the three metals analysed, Pb was found to have the highest percentage of removal by washing followed by Cu and Zn. This is not unexpected as Pb is the main metal released to the atmosphere through the exhausts of automobiles. The amount of metals adsorbed to pine leaves was higher than that adsorbed to oleander leaves. This is inspite of the broad leaves of oleander compared to pine. This could be explained by the sticky resins on pine leaves that might trap and keep pollutants attached to leaf surface.

Table 4. Effect of leaf washing on metal concentrations in two urban roadside plants collected from Amman, Jordan in July 2005.

Plant			
Pine:	Pb	Cu	Zn
washed	1.75±0.22	3.87±0.48	12.51±0.56
nonwashed	17.35±1.69	17.18±0.85	17.37±.34
p value	<0.001	<0.001	<0.001
% removal	89.91	77.47	27.98
Oleander:			
washed	2.67±0.40	6.17±0.79	12.86±0.74
nonwashed	7.92±0.28	12.42±1.41	16.45±0.53
p value	<0.001	0.005	0.003
% removal	66.29	50.72	21.82

Values represent means ± SE ($\mu g\,g^{-1}$ dry weight), n= 6.

Results obtained in the present study for both plants confirmed that Pb is the main metal deposited on plant leaves in urban environments followed by Cu then Zn. Washing leaves of oleander from urbanroside from Turkey was found ro remove 56%, 38% and 36% of Pb, Cu and Zn, respectively (Aksoy & Öztürk, 1997). These results follow the same order as ours, however, the percentage of removal for Pb and Cu of the present study are clearly higher than those of the above-mentioned refernce. This indicates higher rates of atmospheric deposition of Pb and Cu in Amman. Washing leaves of *Inula viscosa* from the West Bank was found to remove 67% of Pb (Swaileh et al. 2004). This is very close to the percent obtained by the present study (66%) for oleander leaves.

Leaf age usually affects its metal concentrations. This becomes of great importance when comparing results of different studies where difference in leaf size (age) between studies might lead to misleading results. Therefore, we compared metal concentrations in new (apical) leaves and old fully-grown leaves (Table 5). New and old leaves of both cypress and oleander were found to differ significantly in their Pb and Zn concentrations. Pb is a nonessential metal that was found to accumulate with leaf age while Zn was found to be less in old leaves of both plants analysed. Old leaves were containing almost 3-4 times as much lead

Table 5. Metal accumulation with leaf age of two urban roadside plants collected from Amman, Jordan in July 2005.

Plant	Pb	Cu	Zn
Cypress:			
new leaves	1.45±0.16	5.13±0.24	14.9±0.14
old leaves	3.87±0.43	4.75±0.39	13.39±0.54
p value	0.002	0.421	0.038
Oleander:			
new leaves	0.93±0.03	7.12±1.00	18.04±0.33
old leaves	3.97±0.26	6.84±0.77	14.36±.84
p value	<0.001	0.828	0.005

Values represent means ± SE ($\mu g \cdot g^{-1}$ dry weight), *n*=6.

as new ones. This is in accordance with a previous study about *Inula visosa* (Swaileh et al. 2004) where old leaves were containing 3 times as Pb as new ones. On the other hand, Zn is an essential metal that is under some physiological regulation in plants. This includes translocation from old to new leaves.

Since the prevailing wind in Jordan is westerly, plant samples from the eastern and werstern sides of the highway connecting the capital to the airport were taken and analysed separately. Samples of cypress and oleander obtained from the eastern side of the highway were found to have significantly more Pb and Zn than those from the western side (Table 6). This indicates the effect of the prevailing wind in transporting pollutants from west to east sides of the highway. Cu did not not vary significantly in plants from both sides of the road. Jaradat and Momani (1999) observed similar results for the three metals in *Anabasis articulata* along a highway that extends from Amman to the southern parts of the Kingdom.

Table 6. Metal levels in urban plants collected from eastern and western sides of streets of Amman, Jordan in July 2005.

Plant	Pb	Cu	Zn
Cypress:			
East of road	4.03±0.40	5.08±0.48	14.55±0.31
West of road	2.84±0.19	4.35±0.6	12.33±0.27
p value	0.031	0.371	<0.001
Oleander:			
East of road	3.62±0.40	6.57±1.30	17.25±0.55
West of road	2.19±0.24	6.12±0.86	13.80±0.77
p value	0.015	0.784	0.005

Values represent means ± SE ($\mu g \cdot g^{-1}$ dry weight), *n*= 6.

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