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Heavy Metal Accumulation in Some Natural and Exotic Plants in Samsun City

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Abstract
The aim of this study was to estimate the level of some trace metal accumulation (Pb, Cd, Zn and Cu) in the leaves, needles, and twigs of some natural and exotic tree and shrub species which were selected and tested as a biomonitors of these heavy metals grown in the centre and suburbs (Atakum) of Samsun, Turkey polluted by burning fossil fuels and heavy traffic conditions from December 2007 to August 2008. Air pollution from traffic density was very important for Samsun in both the winter and summer periods. Because of this reason leaf and twig samples of these species were collected in winter and summer separately. Statistically significant differences were found among the studied species regarding studied heavy metals. The highest heavy metal concentrations were found in *M. grandiflora*, although heavy metal concentrations may be different according to the studied species, sampling points and sampling periods. According to the obtained data it was found that *M. grandiflora*, *Ligustrum vulgare* and *Phoenix dactylifera* can be used as biomonitors (i.e. the highest Cu concentrations were found in Samsun city in *P. dactylifera* leaves (45.10) and *M. grandiflora* leaves (62.00) and the highest Zn concentration was found in *L. vulgare* leaves (69.58) during the summer. Because these species accumulated higher concentrations of heavy metals in their tissues as compared to other species. Finally, it was found that different parts of evergreen plants (i.e. leaves and twigs) can be used as biomonitors in determining heavy metal pollution.
Keywords: Biomonitoring, evergreen, exotic plants, plant tissues, urban and suburb areas.

Samsun İlinde Bulunan Bazı Doğal ve Egzotik Bitkilerde Ağır Metal Birikimi

Özet
Bu çalışmanın amacı trafik yoğunluğu ve fosil yakıtların kullanımı sonucu kirliliğe maruz kalan Samsun il merkezi (Türkiye) ve çevresinde (Atakum)'da seçilen bazı doğal ve egzotik ağaç ve çalı türlerinin yaprak, iğne yaprak ve dallarında Kaım 2007-Ağustos 2008 tarihleir arasında bazı ağır metallerin (Pb, Cd, Zn ve Cu) düzeyini ve bu türlerin biyomonitor (biyolojik gözlem) özelliklerini belirlemektir. Samsun ilinde trafik yoğunluğundan kaynaklanan hava kirliliği gerek kışın ve gerekse yazın çok önemlidir. Bu nedenle türlerin yaprak ve dal örnekleri kışın ve yazın ayrı ayrı toplanmıştır. Çalışılan türler arasında çalışılan ağır metaller yönünden istatistiksel olarak önemli farklılıklar bulunmuştur. Ağır metal konsantrasyonlarının çalışılan türlere, çalışılan lokalitelere ve örnekleme zamanına göre değişebilmesine karşın en yüksek ağır metal konsantrasyonları *Magnolia grandiflora*'da bulunmuştur. Elde edilen verilere göre *M. grandiflora*, *L. vulgare* ve *P. dactylifera*'nın biyomonitor olarak kullanılabilecekleri bulunmuştur (örneğin; Samsun ilinde yazın en yüksek Cu konsantrasyonları *P. dactylifera* (45,10) and *M. grandiflora* yapraklarında (62,00) ve en yüksek Zn konsantrasyonu *L. vulgare* yapraklarında (69,58) bulunmuştur). Bunun nedeni, bu türlerin diğer türlere göre dokularında daha fazla konsantrasyonlarda ağır metal biriktirebilmeleridir. Sonuç olarak herdem yeşil türlerin farklı kısımlarının (örneğin; yaprak ve dalları) ağır metal kirliliğinin tayininde biyomonitor olarak kullanılabilecekleri bulunmuştur.
Anahtar Kelimeler: Biyolojik gözlem, bitki dokuları, egzotik bitkiler, herdem yeşil, şehir merkezi ve çevresi.

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INTRODUCTION

Increasing industralization and human activities intensify the emission of various pollutants into the environment and introduce various harmful substances into the atmosphere. Air pollution is aesthetically offensive and can be a genuine health hazard to human as well as plants (Onder and Dursun 2006, Baslar et al. 2009). The emission of

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toxic substances into the environment has spread from industrialized countries. Many industrial plants and especially heavy traffic may emit heavy metals into the atmosphere.

Fossil fuels contain many kinds of heavy metals which are emitted during the combustion of those fuels (Leygonie 1993). Furthermore, the wear of auto tires, degradation of parts and greases, peeling paint, and metals in catalysts are all suspected as sources of heavy metal pollution (Sadiq et al. 1989, Wei and Morrison 1994, Monaci et al. 2000, Ozakı et al. 2004a, Suzuki et al. 2009). Traffic pollutants include potentially toxic metals for health like lead, cadmium, copper, and zinc (Ozakı et al. 2004b, Viard et al. 2004).

In recent years, it has been shown that lead levels in soil and vegetation has increased considerably due to traffic pollution, i.e. usage of leaded petrol and exhaust combustion (Ötvös et al. 2003). This problem rises as daily traffic increases (Wheeler and Rolfe 1979). A report was made which confirmed that the main source of air pollution in city areas of Turkey was due to the amount of traffic on the roads using leaded petrol (Markert 1994, Soylak et al. 2000, Onder and Dursun 2006). However, due to the phasing out of leaded petrol Zn was as a more reliable tracer of motor vehicle emissions than Pb (Oliva and Rautio 2004a). As city populations increase, so does the demand for creating more industry which adds to the problems already in existence. Over the years, like many other developed countries, Turkey's environmental policy makers did not consider these problems an issue. Therefore, they were not able to forecast the seriousness of the problems which have now arisen (Çelik et al. 2005).

One of the first attempts for the assessment of environmental pollution coming from exhaust gases of automobiles in traffic by using plants is based on the analyses of different trees, grasses, and vegetables that grow near highways and cities, which was used as a common method in the early 1960s. Later on, this problem became the object of extensive investigation by many researchers (Markert 1993, Aksoy and Öztürk 1996, Aksoy and Demirezen 2006). Although, higher plants are not as suitable biomonitors as lichens and mosses, in highly polluted areas in an industrial or urban environment, where lichens and mosses are often absent, higher plants can act as appropriate indicators and biomonitors (Tomaševic et al. 2008). The sampling use of plant tissues has long been shown to be an effective indicator of atmospheric pollution (Goodman and Roberts 1971). Vegetation is an effective indicator of the impact of a pollution source in its vicinity, because most plants have the ability to accumulate heavy metal so that their metal levels are much higher than those in the air. Further, the effect observed is a time-averaged result, which will be more reliable than that obtained from direct determination of the pollutant concentrations in air for a short period. Hence, analyzing plant tissues can give better results in terms of sensitivity and reproducibility (Lau and Luk 2001).

The aim of this study was to estimate the level of some trace metal accumulation (Pb, Cd, Zn and Cu) in the leaves, needles, and twigs of some natural and exotic tree, and shrub species which were selected and tested as biomonitors of these heavy metals grown in the centre and suburbs (Atakum) of Samsun, Turkey polluted by burning fossil fuels and heavy traffic conditions.

MATERIAL AND METHODS

Sampling procedure

In this investigation, the effect of environmental pollution on the deposition of heavy metals on trees was investigated by analyzing four heavy metal (Pb, Cd, Zn and Cu) concentrations of 10 exotic and natural tree and shrub species (*Laurocerasus officinalis* Roemer (Rosaceae), *Eucalyptus camaldulensis* Dehnhardt (Myrtaceae), *Picea abies* (L.) Karst (Pinaceae) , *Acacia cyanophylla* L. (Mimosaceae), *Clematis vitalba* L. (Ranunculaceae), *Olea europaea* L.var.*europaea* (Oleaceae), *Platanus orientalis* L. (Platanaceae), *Ligustrum vulgare* L. (Oleaceae), *Magnolia grandiflora* L. (Magnoliaceae) and *Phoenix dactylifera* L. (Arecaceae)) obtained from the leaves, needles, and twigs, separately. These species are dominant in the green areas of Samsun. For this reason the leaves and twigs of these species were used in this investigation.

Leaf and twig samples for the metal accumulation were collected from two sampling points. Samsun city centre, one of the sample points, which has the highest traffic flow with an average of 6000 vehicle hr-1 according to the records of the Samsun Security Depatment. The second sample point- Atakum (the suburb of the city) has a lower traffic flow (mean 2000 vehicle hr^{-1}) than that the centre of the city.

On the other hand, air pollution from traffic density was very important for Samsun in both the winter and summer period. Because of this reason leaf and twig samples of these species were collected in winter and summer separately.

Using polyethylene gloves, five leaves and twigs samples per specimen were cut off with teflon coated stainless steel scissors. All specimens per sampling episode were taken from the same height and at the same time. Samples were taken from the side facing the highway of the crown. Earlier findings suggested that sampling from different sides of the crown did not affect heavy metal concentrations in leaves (Bargagli 1998). All plant samples were sealed in polyethylene bags and transported to the laboratory.

Plant analysis

In the laboratory leaf and twig samples were dried to a constant weight at 60°C with a microwave oven then 0.5 g of the dried leaf samples were powdered and extracted with a mixture of concentrated HNO_3 $HClO_4$ (3:1). This digest was then filtered through a Whatman filter paper No 42. Concentrations of heavy metals (ppm g^{-1}dry wt) were determined using a Perkin Elmer 2280 atomic absorption spectrophotometer using an air/acetylene flame (Allen et al. 1986). In AAS analyses, calibration graphs were obtained by a linear calibration model using eight working elemental standard solutions (WAKO Pure Chemical Industries Ltd., Japan). The obtained calibration graphs were all of excellent quality, always presenting the correlation coefficient r^2 0.999.

Repeated multivariate analysis of variance (R-MANOVA) and Tukey's honestly significant difference (HSD) tests were carried out by using SPSS 10.0 version. Data was tested for normality using the Kolmogorov-Smirnov test (Anonymous 1999) .

RESULTS

The aritmetic mean (X_a) and standard deviation (S_a) of trace metal concentrations of the studied species and results of Tukey (HSD) test at both sampling points in the winter and summer periods in 2007 are presented in Figs. 1-4. Results of the repeated measures of variance analysis (R-MANOVA) between the species, plant tissues, sampling points, and sampling periods are also given in Table 1.

The highest copper (Cu) concentrations for the

Tablo 1. Statistical differences between sampling points,sampling periods, plant tissues and species by R-MANOVA test.

Source	Dependent variable	df	F- value	Sig
Sampling point	Cadmium	1	27.938	.000**
	Lead	1	619.294	.000**
	Zinc	1	753.701	.000**
	Copper	1	869.740	.000**
Sampling period	Cadmium	1	105.722	.000**
	Lead	1	1474.865	.000**
	Zinc	1	4.588	.034*
	Copper	1	1610.409	.000**
Species	Cadmium	9	10.764	.000**
	Lead	9	128.632	.000**
	Zinc	9	670.533	.000**
	Copper	9	881.595	.000**
Plant tissue	Cadmium	2	1.083	.341NS
	Lead	2	94.696	.000**
	Zinc	2	56.999	.000**
	Copper	2	74.005	.000**
Sampling point * Sampling period	Cadmium	1	2.285	.132NS
	Lead	1	45.786	.000**
	Zinc	1	13.698	.000**
	Copper	1	58.581	.000**
Sampling point * Species	Cadmium	9	.816	.602NS
	Lead	9	50.510	.000**
	Zinc	9	47.811	.000**
	Copper	9	111.594	.000**
Sampling Period*Species	Cadmium	9	21.315	.000**
	Lead	9	135.322	.000**
	Zinc	9	183.226	.000**
	Copper	9	751.362	.000**
Sampling Point * Sampling Period * Species	Cadmium	9	3.134	.002**
	Lead	9	68.265	.000**
	Zinc	9	101.348	.000**
	Copper	9	41.213	.000**
Sampling Pont * Plant Tissue	Cadmium	1	1.701	.194NS
	Lead	1	55.326	.000**
	Zinc	1	12.559	.001**
	Copper	1	.031	.861NS
Sampling Period * Plant Tissue	Cadmium	1	1.748	.188NS
	Lead	1	243.950	.000**
	Zinc	1	78.497	.000**
	Copper	1	247.375	.000**
Sampling Point * Sampling Period * Plant Tissue	Cadmium	1	.260	.611NS
	Lead	1	.838	.361NS
	Zinc	1	2.010	.158NS
	Copper	1	5.239	.023*
Species * Plant Tissue	Cadmium	18	11.490	.000**
	Lead	18	44.568	.000**
	Zinc	18	107.626	.000**
	Copper	18	299.328	.000**
Sampling Point * Species * Plant Tissue	Cadmium	9	3.012	.002**
	Lead	9	17.84	.000**
	Zinc	9	18.588	.000**
	Copper	9	19.365	.000**
Sampling Period * Species * Plant Tissue	Cadmium	9	20.005	.000**
	Lead	9	27.197	.000**
	Zinc	9	210.617	.000**
	Copper	9	176.409	.000**
Sampling point * Sampling period * Species * Plant tissue	Cadmium	9	3.991	.000**
	Lead	9	11.696	.000**
	Zinc	9	26.015	.000**
	Copper	9	36.389	.000**
Error	Cadmium	180		
	Lead	180		
	Zinc	180		
	Copper	180		
Total	Cadmium	270		
	Lead	270		
	Zinc	270		
	Copper	270		
Corrected Total	Cadmium	269		
	Lead	269		
	Zinc	269		
	Copper	269		

**p< 0.01, *p< 0.05, NS: Not Significant, df: Degrees of freedom, Sig: Significance two sampling points were detected in the leaf samples of *P. dactilyfera*. At the same time Cu concentrations in the twigs of this species was also at very high levels (except for *M. grandiflora*). The second highest level for Cu accumulation in the city centre was detected in both the leaves and twigs of *M. grandiflora*. The mean copper concentration was 35 ppm in the leaves and 24 ppm in the twigs for *M. grandiflora*. Similarly a relatively high concentration of copper was found in the leaves of *A. cyanohylla* in the Atakum (suburb of the city) region. Low levels of copper concentrations were detected in the leaves of *P. orientalis* (<5 ppm) and *C. vitalba* (<6 ppm) in the city centre and in the twigs of *E. camaldulensis* in the Atakum region. In general, Cu concentrations was two times that in *P. dactylifera* than the other 9 species at both sampling points. On the other hand, accumulation of Cu in the leaf samples of the studied species was higher than in the twigs (except for *P. orientalis*, *L. vulgare* and *O. europaea* var. *europaea*).

Zinc levels in the leaves and twigs of *L.vulgare* had the highest values in the samples from the city center in the winter period. The overall mean concentrations of Zn were 70 ppm and 55 ppm in the leaf and twig samples, respectively. In the summer period, the highest Zn concentrations in the city centre was found in the twigs of *M. grandiflora* and in the leaves of *C. vitalba*. Similarly, in the Atakum region, the high Zn levels were detected in the leaf samples of *A. cyanopylla* and in the twigs of *L. vulgare* for the winter period. However, in the summer *M. grandiflora* had the highest Zn concentrations in both leaves and twigs. Thus, leaf and twig concentrations of Zn in both *L. vulgare* and *M. grandiflora* were statistically higher than other tree species (Figure 1b, 2b, 3b and 4b). These results mean that *L. vulgare* and *M. grandiflora* are not able to detect the concentration between the tissues and sampling points, even if its Zn concentrations are high, indicating that these species are better biomonitors of Zn. Accordingly, the leaves of *A. cyanophylla* and *C. vitalba* may be useful for monitoring Zn pollution. Zn concentrations were the lowest in the leaf and twig samples of *P. orientalis* and *L. officinalis*.

Lead concentrations in the leaves of *M. grandiflora* and *A. cyanopylla* were at a maximum and at very high levels in comparison with other species for both sampling points in the winter period. Mean concentrations of Pb were about 12 ppm and 8 ppm in the leaf samples of *M. grandiflora* and *A. cyanophylla* in the city centre. Pb concentrations in other species were lower and generally similar to each other. In the Atakum region the mean concentration of Pb for both species was 3.5 ppm. The lowest Pb concentrations were observed in the twig samples of *P. orientalis* for both sampling points in the winter period. Pb concentrations of this species were about 1.2 ppm. Quite different values were reported for the summer period at the sampling points. Higher Pb concentrations in the city centre were detected in the leaf samples of *E. camaldulensis*, *P. abies* and *A. cyanopylla*, respectively. Accumulation of Pb in the leaves of these species was much higher than the twigs. For example, the Pb concentrations were 8 times higher in the leaves of *P. abies* than the twig samples. However, in the Atakum region Olea europaea var. europaea, *P. dactylifera* and *P. orientalis* represented obviously higher Pb concentrations than other species and these values were much higher in the twig samples than in the leaves (about 4 times higher). The lowest Pb concentrations were observed in the leaf and twig samples of *L. officinalis* and *L. vulgare* for the summer period at the sampling points.

The Cd values in our samples in general are very low (< 0.1 ppm), but the highest values were recorded in the twig and leaf samples of *P. abies* for both sampling points in the winter period. The maximum Cd concentrations were 0.15 ppm and 0.07 ppm in the twig and leaf samples of *P. abies*. However, the lowest Cd concentrations were observed in the twigs of the same species in the city centre for the summer period. In summer, the highest Cd concentrations were in the twig samples of *M. grandiflora* which is similar to other studied heavy metals for both sampling points. The twig and leaf samples of all other studied species demonstrated low Cd concentrations (0.12 or < 0.12) whereas, in the twig samples of *M. grandiflora*, it was observed to be two times higher. Accordingly the leaves of *C. vitalba* may be also useful for monitoring Cd pollution. The lowest Cd concentrations were observed in the leaf and twig samples of *L. officinalis*.

Variance analysis for any metal showed that there were significant differences ($p<0.01$) between the sampling points. There were also significant differences between sampling periods for all metals ($p<0.01$ for Pb, Cd and Cu; $p<0.05$ for Zn). R-

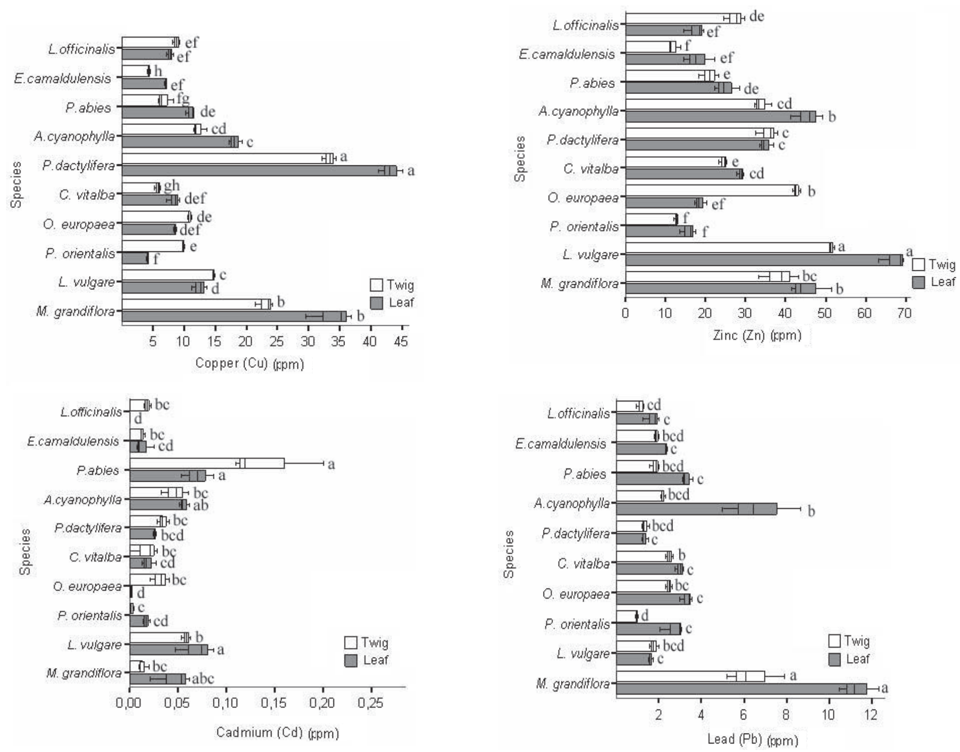

Fig. 1. Mean heavy metal concentrations and Tukey HSD groups measured at the Samsun city centre in winter: a) copper; b)zinc; c) cadmium; d) lead (Different lowercase letters indicate significant differences between sites. Vertical lines indicate standart error).

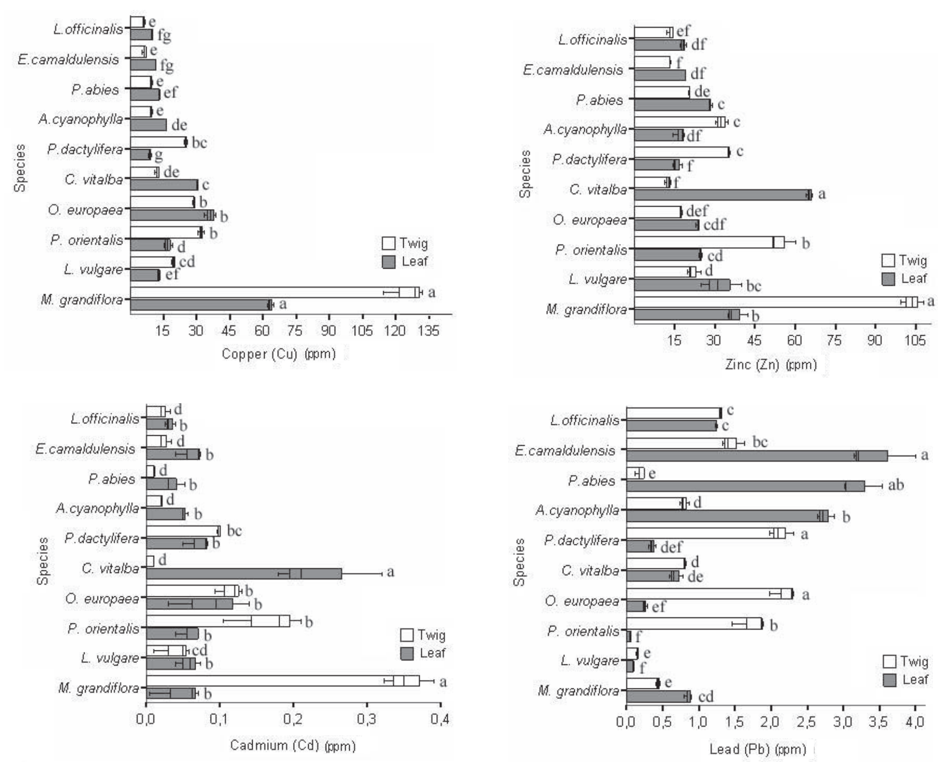

Fig. 2. Mean heavy metal concentrations and Tukey HSD groups measured at the Samsun city centre in summer: a) , copper; b)zinc; c) cadmium; d) lead (Different lowercase letters indicate significant differences between sites. Vertical lines indicate standart error).

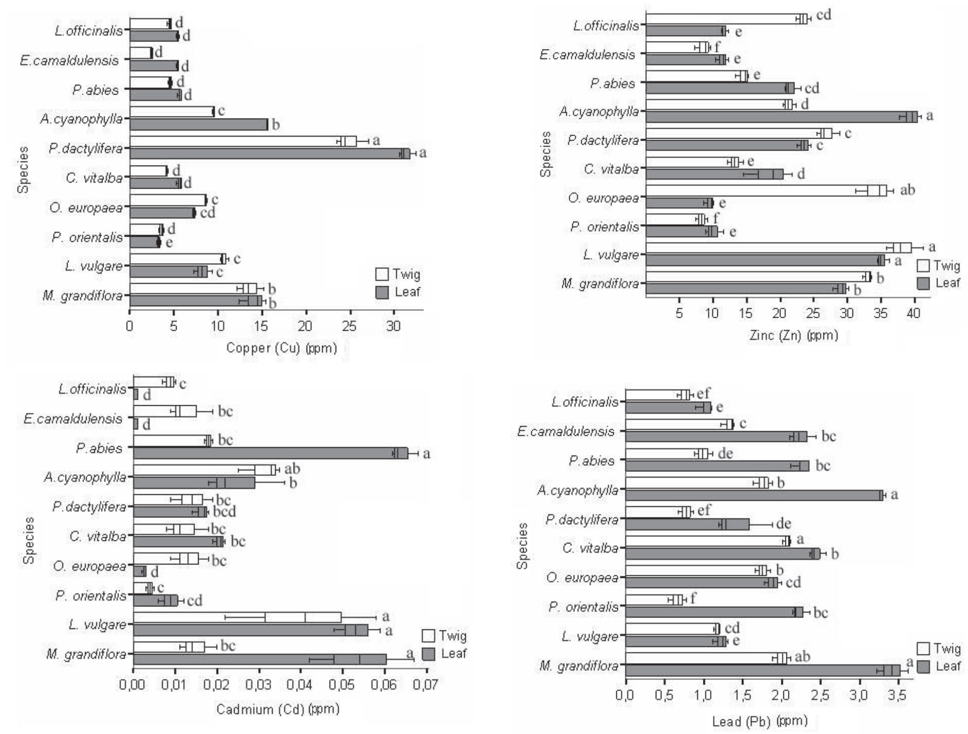

Fig. 3. Mean heavy metal concentrations and Tukey HSD groups measured at the Atakum (suburb) in winter: a) copper; b) zinc; c) cadmium; d) lead (Different lowercase letters indicate significant differences between sites. Vertical lines indicate standart error).

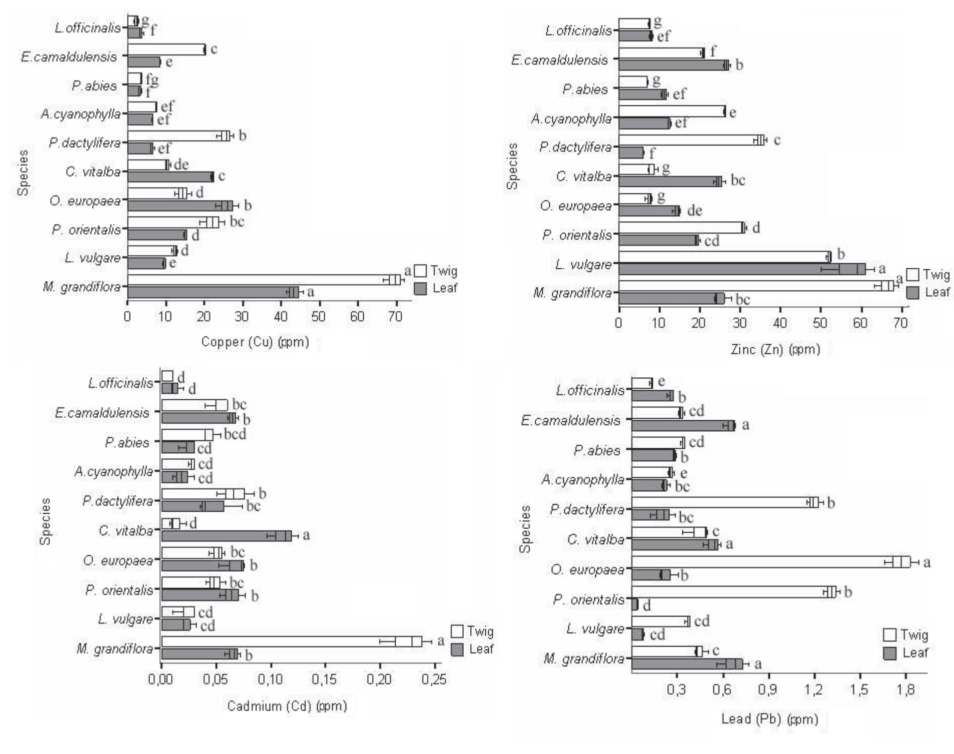

Fig. 4. Mean heavy metal concentrations and Tukey HSD groups measured at the Atakum (suburb) in summer: a)copper; b) zinc; c) cadmium; d) lead (Different lowercase letters indicate significant differences between sites. Vertical lines indicate standart error).

MANOVA analysis indicated that there were significant differences between plant species for any metal. There were no significant differences ($p>0.05$) between the Cd concentrations of plant tissues whereas, there were significant differences for all other metals.

As seen in the variance analysis (Table 1) there weren't statistically significant differences between sampling point-sampling period interaction for Cd levels. However, there were significant differences for Pb, Zn and Cu between sampling point-sampling period interaction. There wasn't significant differences between sampling point-species interaction for Cd levels. But there were significant differences for all other elements between sampling point-species interaction.

For both sampling period-species and sampling point-sampling period-species interaction there were significant differences ($p<0.01$) between all studied heavy metals concentrations. According to the results there were no significant differences for Cd and Cu levels between sampling point-plant tissue interaction. On the other hand, there were significant differences for Pb and Zn levels between this interaction.

Results of variance analysis showed that there were significant differences ($p<0.01$) for Cu, Zn, and Pb between sampling period-plant tissue interaction whereas, there was not a significant difference ($p>0.05$) for Cd between these parameters. On the other hand, statistical analysis indicated that there was significant differences ($p<0.01$) only for Cu between sampling point-sampling period-plant tissue interaction. However, there were not significant differences between these parameters for all other heavy metals. Furthermore, there were significant differences for all heavy metals between species-plant tissue interaction according to R-MANOVA test.

Taking into account the interaction between sampling point-species-plant tissue there were significant differences for all heavy metals. There were also significant differences between sampling period-species-plant tissue and sampling point-sampling period-species-plant tissue

DISCUSSION

High concentrations of heavy metals in the plant tissue show pollution levels of air or soil by heavy metal. Metal uptake in higher plants takes place through the roots and somewhat via the leaves, which makes it difficult to distinguish whether the accumulated elements in leaves originate from the soil or from the air (Markert 1993, Bargagli 1998, Tomaševic et al. 2008). Pb in leaves is considered to originate mainly from atmospheric deposition (Harrison and Johnston 1987).

Copper is a minor trace metal, with 70% copper in leaves contained in the chloroplast of land plants (Wilkinson 1994). Disturbances in Cu supply can cause significant modifications of biochemical processes in plants, leading to lower yields and quality of agricultural crops (Onder and Dursun 2006). An excessive supply of Cu causes symptoms of chlorosis that are similar to the symptoms of iron deficiency (Bergman 1983). According to Yılmaz et al. (2006), 5 to 20 ppm Cu was normal, while less than 4 ppm was considered deficient and above 20 ppm was considered toxic for plant growth. In our study the values of Cu varied between 4-44 ppm for the winter period, 5-135 ppm for the summer period in the Samsun city-centre and 2.5-30 ppm for the winter period, and 2-70 ppm for the summer period in the Atakum region. Our results showed that the Cu concentrations were far above the normal levels presented by Yılmaz et. al. (2006) and Suzuki et al. (2009), implying that Cu could be potentially harmful on local vegetation and environments in the future if the emission of pollutants is not controlled effectively. According to the statistical results, *P. dactylifera* and *M. grandiflora* could be used as bioindicators for Cu contamination. Because the highest Cu concentrations were observed in the leaf and twig samples of these two species. Low levels of copper were found in the leaves of *P. dactylifera* by Aksoy and Ozturk (1996) and by Dıvrıklı et al. (2006). They reported 3.04-5.64 ppm and 3.3-6.2 ppm of Cu in the leaf samples of *P. dactylifera*. In our study Cu concentrations in the leaf samples for the winter period are very high and results for the summer period are very near to the values reported by Aksoy and Ozturk (1996) and Dıvrıklı (2006). However, Cu concentrations in the twig samples are very high in both sampling periods than those cited above. Traffic-related Cu in general enters the environment mainly by the abrasion of metallic parts in cars (Dıvrıklı et al. 2006). The other main reason for high concentrations of Cu in plants localized on urban roadsides is exhaust emissions (Schäfer et al. 1998). The reason for the high values of Cu in the Samsun city centre which have high traffic density could be due to exhaust emissions.

Zn concentrations were significantly different for the two sampling points and the two sampling periods (Table 1). Zn is an essential element in all organisms and plays an important role in the biosynthesis of enzymes, auxins, and some proteins. Plants with symptoms of Zn deficiency experience a retarded elongation of cells. A critical toxic level of Zn in the leaves is about 100 ppm in dry plant matter (Allen et al. 1974, Yılmaz and Zengin 2003, Onder and Dursun 2006). High levels of Zn in plants may cause a loss of production and the low levels may cause deformation of leaves (Bucher and Schenk 2000). According to Iqbal et al. (1998) plant species show differential behavior in regards, to Zn concentration In general zinc is not at harmful levels one major threat to the environment in our study. Only zinc concentrations in twig samples of *M. grandiflora* were higher than the background values reported by Allen et al. (1974), Yılmaz and Zengin (2003), and Onder and Dursun (2006) in the Samsun city centre in the summer. It has been reported that Zn concentrations in *Ligustrum*, *Salix*, and *Populus* were between 15.5-42.2 ppm, 20.7-94.7, ppm and 26.1-139 ppm, respectively in several studies (Sawidis et al. 1995). Zn concentrations in our study except for *L. vulgare* were not very high and did not exceed the upper limit cited by Sawidis et al. (2001). However, Zn concentrations in *L. vulgare* during this study were between 63.3-69.5 ppm in the leaves, and 50.9-52.3 ppm in twigs for the winter period and 25.04-31.01 ppm in the leaves, and 20.01-25.02 in the twigs for the summer period in the Samsun city centre. In the Atakum region which has low traffic density, these values ranged between 34.45-36.2 ppm in the leaves, and 35.7-41.2 ppm in the twigs for winter period and 58.8-69.1 ppm in the leaves, and 51.3-52.4 ppm in the twigs for the summer period. All these results were far above what was cited by Sawidis et al. (1995, 2001).

Many workers have studied the toxic effect of Cd on plants. Cadmium, one of the most dangerous pollutants for organisms, is mainly derived from combustion of accumulators and carburetors of vehicles (Dıvrıklı et al. 2006) and can be actively absorbed by plant roots and easily transported within plants (Kuang et al. 2007). In general, toxicity has been reported to cause a reduction in the plant growth as well as chlorosis (Yılmaz et al. 2006). Cd values for unpolluted natural environments should lie between 0.01-0.03 ppm (Allen 1974) and the normal range was reported as 0.05-0.5 ppm by Onder and Dursun (2006). The Cd values in our samples ranged between 0.01-0.15 ppm for the winter period and 0.01-0.38 ppm for the summer period in the city centre. These values ranged between 0.01-0.07 ppm for the winter period and 0.01-0.24 ppm for the summer period in the Atakum region. These values exceeded the Cd level for unpolluted areas presented by Allen et al., (1974). However, our results were below the normal level presented by Kabata-Pendias and Piotrowska (1984). Aksoy and Ozturk (1997) reported 0.02-0.72 μg g-1 of Cd in the leaves of *N. oleander*. These values are higher than ours. On the other hand, Aksoy and Ozturk (1996) have also reported 603 ppm of Cd for the leaf samples of *P. dactylifera*. Similarly, very high concentrations of Cd in the leaf samples of *P. dactylifera* was reported by Pillay et al. (2002) and Dıvrıklı et al. (2006). The value of Cd in their studies varied between 50-125 ppm and 77.2-136.3, respectively. Our results were much lower than those cited above.

The occurrence of Pb in higher amounts is due to traffic volume (Cassales 1998, El-Hasan et al. 2002). Average Pb concentration in plants is less than 10 ppm (Kabata-Pendias and Piotrowska 1984). Allen (1989) considered a much lower value of 3 ppm as a normal natural level for plants. Measurements of Pb concentrations in the leaf and twigs varied between 1.1-12 ppm in the Samsun city centre and 0.7-3.5 ppm in the Atakum region in this study. The highest Pb concentrations were found in the leaf samples of *M. grandiflora* in the Samsun city centre. The close relationship between lead concentrations and traffic intensity has been demonstrated in detail by many authors (Gromow and Emelina 1994, Li et al. 2006, Viard et al. 2004, Onder and Dursun 2006). In this study, there was also linear correlation between high Pb level and heavy traffic in the Samsun city centre, and on the contrary in the Atakum region. Moreover, Aksoy and Öztürk (1997) have pointed out the relationship between Pb amounts and exhaust from vehicles. Load exhaust from cars is considered as one of the major sources of contamination of Pb in Turkey. Unfortunately, leaded gasoline is still the prevailing traffic fuel in Turkey and some old versions of cars consume only leaded petrol (Çelik et al. 2005).

According to Aksoy and Ozturk (1996), Pb concentrations in the leaves of *P. dactylifera* ranged between 2.18-24.37 ppm. Similarly, Bu-Olayan and Thomas (2002) have reported 1.77-13.42 ppm of Pb in the leaf samples of *P. dactylifera*. Our results for this species were lower than values reported by Aksoy and Ozturk (1996) and Bu-Olayan and Thomas (2002). Besides, Bu-Olayan and Thomas (2002) have pointed out that lead leaf concentrations in P. dactylifera were higher than woody parts of this species. But these results were inversely related with ours obtained for *P. dactylifera*. Pb concentrations in the twig samples of *P. dactylifera* were higher in the Atakum region for the winter period. On the other hand, Pyatt (2002) reported that Pb concentrations in both the leaves and woody parts of *A. retinoides* were higher than Cu concentrations. But our results obtained from *A. cyanophylla* belonging to the same genus inversely related with the results reported by Pyatt (2002) for both sampling points and periods.

Plant species with acicular leaves accumulate much lower concentrations of Pb than that other species (Çavuşoğlu and Çavuşoğlu 2005). Our study has demonstrated similar results for *P. abies*. Pb concentrations were lower in the needles of *P. abies* than that of other species. Similar results for Pb concentrations have been pointed out by other studies with different plant species in Europe (El-Hasan et al. 2002).

Zn concentrations were higher in all studied species than that Pb. Lead is considered more of a floem-immobile element than zinc (Aksoy and Ozturk 1997). Low Pb concentrations may be interpretated by floem-immobility of this element, indicating translocation and accumulation to aerial parts is limited.

Statistically significant differences were found among studied species regarding studied heavy metals like several studies (Tomaševic et al. 2008, Huseyinova et al. 2009). The highest heavy metal concentrations were found in *M. grandiflora*, although heavy metal concentrations may be differed according to studied species, sampling points, and sampling periods.

According to Oliva and Rautio (2004) heavy metal concentrations were higher in the leaves than woody parts of *Nerium oleander* and *Pinus pinea*. In general our results coincide with that of Oliva and Mingorance (2004). However, in our study Pb concentrations were higher in leaf samples for the winter period whereas, these values were higher in the twigs for the summer period. These weren't considered seasonal changes in the cited study. Our study demonstrated that heavy metal accumulation may be varied in plant tissues with seasonal changes. Besides, Tomaševic et al. (2008) implied a species-specific element accumulation. Li et al. (2006) pointed out that there were wide variations of heavy metal concentrations both among plant species and within different plant tissues of the same species. Our results coincide with that of Li et al. (2006) and Tomaševic et al. (2008). There were significant differences between sampling points and sampling periods for accumulation of heavy metals in our study.

Although the mean heavy metal concentrations in evergreen and deciduous tree species was determined in earlier studies, there are not enough concrete findings about concentration differences in different tissues of plant species. Furthermore, atmospheric deposition, weather fluctuations, wind direction, and rains may change due to the seasons and it is possible to conclude that, in future biomonitoring studies seasonal changes and different plant tissues should be taken into account.

According to obtained data it was found that *M. grandiflora*, *L. vulgare*, and *P. dactylifera* can be used as biomonitors, because these species accumulated higher concentrations of heavy metals in their tissues as compared to other species. Finally, it has been found that different parts of the evergreen plants (i.e. leaves and twigs) can be used as biomonitors in determining heavy metal pollution.

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