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Research Article

Elaeagnus angustifolia L. as a Biomonitor of Heavy Metal Pollution

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Abstract: The leaves of *Elaeagnus angustifolia* L. *(Elaeagnaceae)* were tested as a possible biomonitor of heavy metal pollution in Kayseri. Concentration of Pb, Cd and Zn were determined in unwashed and washed leaves and soils. Differences between the unwashed and washed samples varied according to the metal pollutant levels. Significant correlations were obtained between the heavy metal concentrations in surface soil and washed leaf samples. *E. angustifolia* was found to be a useful biomonitor of the heavy metals investigated.

Key Words: *Elaeagnus angustifolia*; biomonitor; heavy metal pollution; Kayseri.

Elaeagnus angustifolia L. nın Ağır Metal Kirlenmesinde Bioindikator Olarak Kullanılması

Özet: Bu çalışmada *Elaeagnus angustifolia* L. *(Elaeagnaceae)* bitkisinin yaprakları, Kayseri'de ağır metal kirlenmesinin olası biyolojik monitörü olarak araştırıldı. Yıkanmış ve yıkanmamış bitki örnekleri ve toprak örneklerindeki Pb, Cd ve Zn konsantrasyonu belirlendi. Yıkanmış ve yıkanmamış bitki örnekleri arasında metal kirlenme düzeyleri farklılıklar gösterdi. Yıkanmış bitki yapraklarında ve yüzey topraklarındaki ağır metal konsantrasyonları arasında istatiksel olarak önemli bir ilişki elde edildi. *E. angustifolia*'nın araştırılan ağır metallerin kullanışlı bir biyolojik monitörü olduğu bulundu.

Anahtar Sözcükler: *Elaeagnus angustifolia*, biomonitor, ağırmetal kirlenmesi, Kayseri.

Indroduction

The plant materials such as fungi, lichens, tree bark, tree rings and leaves of higher plants, have been used for many years to detect the deposition, accumulation and distribution of metal pollution. Lower plants; especially mosses and lichens; in view of their higher capacity for metal accumulation are probably the organisms most frequently used for monitoring metal pollution in urban environments (1, 2). Leaves of higher plants have been used for biomonitoring heavy metals since 1950s (2). The past few decades have seen an increase in the use of higher plant leaves as biomonitor of heavy metal pollution in the terrestrial environment (3–5).

Aksoy and Öztürk (4), for example, used date palm leaves to monitor the distribution of airborne Pb, Cd, Zn and Cu in the city of Antalya in Turkey. A comparison of washed and unwashed samples showed that leaf analyses gave a reasonably reliable measure of the total aerial fallout of heavy metals in the studied area.

In Kayseri city, *Elaeagnus angustifolia* L. (*Elaeagnaceae*) a typical urban tree; with a more or less a cosmopolitant distribution; usually occurs along roadside in industrial, urban parks, rural and agricultural areas, even under higher levels of urban pollution. This species shows a broad geographical range, occurring widely in Asia and Europe, particularly in Turkey, Caucasia and Central Asia (6).

Kayseri is located in the Central Anatolia of Turkey. It is a rapidly growing city and its present populations is estimated to be around 978 927, compared to 403 861 in 1950. The city enjoys terrestrial climate with dry hot summer and cold winters. Heavy metals are emitted in to the Kayseri environment from different sources; transportation, industrial activities, fossil fuels, agriculture and other human activities.

The aim of this study is to determine Pb, Cd and Zn concentrations in surface soil and in unwashed and washed leaves of *E. angustifolia* which was tested as a possible biomonitor of heavy metal pollution mentioned in Kayseri.

Materials and Methods

Site selection: Plant and soil samples were taken from different sampling sites. Preferred urban sites for sampling were the most crowded parts of the city centre. Roadside sites were chosen along the Kayseri-Kirsehir highway at 25th km. The traffic density of this road was estimated to be 285 vehicles per hour. Samples from industiralised area were taken from different places between 0-5 m around a single but very large zinc producing industrial establishment (Çinkur Plant) which is nearly 22 km away to the west of the city centre. Suburban sites were chosen from the edge of city which is under a shanty development. For uncontaminated controls, samples were collected from Ali Dagi, about 25 km south-east of Kayseri city.

Sample collection and preparation: Samples of plants and soils were collected from different sites during August, 1996, the number of sites from each category sampled being as follows: industrial site=8, roadside=10, urban=10, suburban=8 and rural area (as control)=8. At each site, soils were sampled from the top 10 cm by means of a stainless steel trowel to avoid contamination. The soil samples were air dried and then passed through a 2 mm sieve. About 200 g (fresh weight) of well developed leaves of *E. angustifolia* were selected and collected. Plant samples were then divided into two sub-samples. One sub-sample was thoroughly washed with running distilled water to remove dust particles, the other remained untreated. All plant samples were oven-dried at 80 °C for 24 hours, milled in a micro-hammer cutter and fed through a 1.5 mm sieve.

Analytical techniques: The method adopted from Berrow and Ure (7) and Paveley and Davies (8) for analysis of heavy metal concentrations in soil samples involved aqua regia digestion. One gram samples of dried and sieved soil materials were ashed in a muffle furnace at 460 °C for 24 hours. The weighed ash was digested in 10 ml Aqua Regia (1 part concentrated HNO_3 to 3 parts HCl) in a digestion tube on the heating block for a total of 9 hours, in the following sequence and duration of temperatures: two hours each at 25 °C, 60 °C and 105 °C, and finally three hours at 125 °C. All digested samples were centrifuged, then made up to volume with 1 % HNO_3.

The method used for plant digestion is same as described earlier by Al-Shayeb *et al.*(2) One gram samples of dried and ground plant material were ashed in a muffle furnace at 460 °C for 24 hours. The weighed ash was digested in concentrated HNO_3 and evaporated to near dryness on a hot-plate. Digested samples were centrifuged, then made up to volume with 1 % HNO_3.

Concentrations of the heavy metals, Pb, Cd and Zn were measured in soil and plant samples by an atomic absorption spectrophotometer (Perkin Elmer model 1100). In order to ascertain the accuracy of the method employed and calibrate for any slight contamination, a reference material was used with every batch (SRM 1547 peach leaves).

The standard error values of the means were calculated for a comparison of site categories. To determine the significance of washing of the leaves, a paired t-test was performed, comparing heavy metal contents of washed and unwashed plants, for each type of site. Significance of comparison of means by ANOVA (F-test) are indicated. Relationships between variables were assessed using linear regression and correlation analyses.

Results and Discussion

The mean concentrations of heavy metals (Pb, Cd and Zn) found in unwashed and washed leaves of *E. angustifolia* in different sites are presented in Tables 1 and 2. The mean heavy metal concentrations in industrial site and urban roadside are slightly higher than the urban, suburban sites, significantly higher than rural sites in washed and unwashed leaves.

The mean concentrations of heavy metals in the soils supporting *E. angustifolia* in the same areas are presented in Table 3. The mean Pb, Cd and Zn concentrations in industrial site are slightly higher than the roadside, urban and suburban sites, significantly higher than rural sites in soil.

The highest pollution levels were found in the samples taken from the industrial sites. It may be concluded that, Çinkur plant is a great pollution source for its surroundings. This plant produced significant levels of metallic Zn, Cd and Pb pollution, due to a lack of filter system in its chimneys. Certainly, a filter system for the flues of the plant might reduce these levels and is thus necessary to bring down this load of heavy metal pollution considerably. Kartal *et al.*(9) studied soil pollution level for six elements around Çinkur plant. They have reported that Pb, Cd and Zn pollution was very high which originates from the zinc-ore used in the factory. The heavy metal levels decrease with an increase in the distance from the factory.

The high heavy metal content in roadside and urban soils and plant samples is mostly due to the density of the traffic which is considered as one of major sources of

	Pb			Cd		
Site	Unwashed	Washed	T-test	Unwashed	Washed	T-test
Industry	180.21 ± 12.2	65.20 ± 3.45	***	3.45 ± 0.12	1.25 ± 0.09	***
Roadside	75.82 ± 10.4	35.25 ± 3.21	***	1.38 ± 0.08	0.66 ± 0.08	***
Urban	50.56 ± 8.6	28.38 ± 3.05	***	1.11 ± 0.09	0.61 ± 0.05	***
Suburban	30.45 ± 5.7	24.32 ± 2.11	**	0.80 ± 0.06	0.60 ± 0.07	**
Rural	16.81 ± 2.1	15.4 ± 1.01	*	0.50 ± 0.04	0.48 ± 0.02	*
F- test	***	***		***	***	

Table 1. Mean Pb and Cd concentrations (μgg^{-1} dry weight) in leaves of *E. angustifolia* collected from different sites of Kayseri, together with standard error of the mean. Significance of means by ANOVA (F-test) and comparison of washed and unwashed leaves by paired t-test are indicated. (Key:*** p<0.001, **p<0.01 and * p<0.05 significance).

Table 2. Mean Zn concentrations (μgg^{-1} dry weight) in leaves of *E. angustifolia* collected from different sites of Kayseri, together with standard error of the mean. Significance of means by ANOVA (F-test) and comparison of washed and unwashed leaves by paired t-test are indicated. (Key:*** p<0.001, **p<0.01 and * p<0.05 significance).

	Zn		
Site	Unwashed	Washed	T-test
Industry	231.26 ± 10.12	102.10 ± 4.31	***
Roadside	83.52 ± 8.51	40.22 ± 2.65	***
Urban	69.14 ± 7.20	37.25 ± 2.25	***
Suburban	38.16 ± 6.08	29.43 ± 2.12	**
Rural	22.08 ± 1.82	20.14 ± 1.01	*
F- test	***	***	

heavy metal contamination. Because unleaded gasoline is expensive and drivers prefer leaded gasoline (2). In Turkey, this results in a high Pb pollution alongside the roads. The latter one is also a major source of heavy metal pollution in Kayseri city.

Washing the leaves significantly reduced the Pb concentrations in *E. angustifolia* from all sites (as indicated by t-test results). A comparison of the amount of metal extracted from unwashed with that from washed leaves (Table 4), shows that removal of the metals from the leaves by washing was significantly different; for example 6-63 % of the Pb was removed by

Table 3. Mean Pb, Cd and Zn concentrations (μgg^{-1} dry weight) in soils collected from different sites of Kayseri, together with standard error of the mean. Significance of comparison of means by ANOVA (F-test) is indicated. (Key:*** p<0.001 significance).

Site	Pb	Cd	Zn
Industry	485.26 ± 25.66	10.21 ± 0.41	1215.25 ± 20.45
Roadside	144.35 ± 12.35	2.15 ± 0.35	165.63 ± 14.12
Urban	120.56 ± 10.24	1.89 ± 0.26	138.32 ± 10.24
Suburban	70.66 ± 8.21	1.25 ± 0.21	110.55 ± 9.55
Rural	40.21 ± 3.15	0.69 ± 0.11	66.12 ± 8.14
F-test	***	***	***

the washing procedure, depending on the pollutant level at the sampling sites. The ability to distinguish airborne and soil borne contamination was assessed by washing the leaves. The results given in Table 4 indicate that there was substantial aerial deposition on the leaves for all three elements, which were removed by washing procedure.

A least squares linear regression was obtained for each of the metals, Pb, Cd, and Zn, between concentrations of the element in surface soils and in the washed leaves of *E. angustifolia*. Table 5 shows the values of the correlation coefficient (r) for each heavy metal. A perusal of the table shows that Zn and Cd are all highly significant at p<0.001, except lead which is also

Table 4. Total percentage of Pb, Cd and Zn removal from the leaves of *E. angustifolia* through washing procedure. Significance of comparison means by ANOVA (F-test) are indicated (Key: *** p<0.001 significant).

Sites	Pb	Cd	Zn
Industrial site	63 ± 5.18	62 ± 3.56	55 ± 4.11
Roadside	53 ± 4.21	50 ± 3.29	50 ± 3.85
Urban	47 ± 4.00	46 ± 3.88	45 ± 4.15
Suburban	26 ± 5.11	25 ± 2.97	23 ± 3.10
Rural	6 ± 2.03	4 ± 1.59	9 ± 2.01
F-test	***	***	***

significant at p<0.01. However, latter is less mobile than other metals determined by us, as such, lower values are obtained in this connection. It can therefore be inferred that with an increase in the amount of heavy metals in soil due to percolation the uptake of heavy metals by *E. angustifolia* also increases. Aksoy and Öztürk (4) investigated *Phoenix dactylifera* L. as a biomonitor of heavy metal pollutions in Antalya province, Turkey. They have reported that correlations between various elements in washed leaves and soils were highly variable (e.g. Pb=0.501, Cd=0.665, Zn=0.886 and Cu=0.798).

Lead is generally added to the environment by aerial deposition alongside the roads in proportion with the density of traffic and distance from the roadside. Hölwarth (10) investigated heavy metal content in needles of *Taxus baccata* L. and reported that high levels of Pb and Cu came from vehicular emissions. Tam *et al.*(11) used surface soil in a survey of roadside heavy metal contamination in Hong Kong and found a significant correlation between traffic density and Pb, Cu and Zn concentrations. Lead is less mobile than Cd and Zn (12) and, although uptake from the soil can raise foliar Pb concentrations, an uptake of Pb through the root system has been demonstrated under greenhouse conditions as well. In the field most uptake has been demonstrated to be through the leaves (13).

Table 5. Relationships between heavy metal concentration in surface soil and the washed leaves of *E. angustifolia* (Key: r, correlation coefficient; **, p<0.01 ***, p<0.001 significant).

Plant	Element	Sample number	*r*
	Pb	44	0.401**
E. angustifolia	Cd	44	0.665***
	Zn	44	0.901***

Elaeagnus angustifolia can survive under a wide temperature range and grows in almost any type of soil. It has pubescent leaves which give it the ability to accumulate deposited dust in large quantities.

According to Wittig (14), the basic criteria for the selection of a species as a biomonitor are that it should be represented in large numbers all over the monitoring area, have a wide geographical range, should be able to differentiate between airborne and soil borne heavy metals, easy to sample and there should be no identification problems. *E. angustifolia* embodies all these criteria and our study fully supports the view that it can be a useful biomonitor all through Turkey, Caucasia and Central Asia, because a highly significant linear regression was obtained for each of the metals Pb, Cd, and Zn between concentrations of the element in surface soil and in the washed leaves of plant.

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