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Carolina poplar (*Populus* × *canadensis* Moench) as a biomonitor of trace elements in Black sea region of Turkey

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Abstract: *In this study, the leaves, bark and the soil supporting Populus x canadensis Moench were tested as a possible biomonitor of trace element pollution in the Middle Black Sea region of Turkey. The investigations were carried out at 23 sites. The leaves, bark and soil were analyzed for Pb^{++}, Cd^{++}, Fe^{++}, Cu^{++} and Zn^{++} contents. The values of Pb^{++}, Cd^{++}, Fe^{++}, Cu^{++} and Zn^{++} in the leaves varied between 14.5-40.0, 0.5-1.5, 135-486, 5.0-14.0 and 43-246 ppm, respectively. In the bark the values were between 15.5-36.5 (Pb^{++}), 1.5-2.0 (Cd^{++}), 39-575 (Fe++), 5.0-14.0 (Cu^{++}) and 40.0 –1468 ppm (Zn^{++}), whereas in the soil values for Pb^{++} were 1.0-4.1 ppm, for Cd^{++} 0.2 ppm, for Fe^{++} 0.6-1.8 ppm, for Cu^{++} 0.1-0.9 ppm and for Zn^{++} 0.1-1.9 ppm. A positive correlation was found between traffic density and the amount of Pb^{++}, Fe^{++} and Cu^{++} in leaves, while a negative correlation was documented for Cd^{++} and Zn^{++}. In the bark samples there was a positive correlation between traffic density and Pb^{++}, and a negative one with Cd^{++}, Fe^{++}, Cu^{++} and Zn^{++}. A positive correlation was determined between traffic density and the amount of Pb^{++}, Fe^{++}, Cu^{++} and Zn^{++} in soil. However, the amount of Cd^{++} was 0.2 ppm and no relationship between Cd^{++} and traffic density was observed.*

Key words: *Populus x canadensis, Trace elements, Pollution*
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Introduction

The accumulation of a trace element in plants confirms its availability in the surrounding environment. The high heavy metal content in urban sites, urban roadsides and soil that results in high concentrations in plant samples from these sites, is mostly due to the density of traffic. One of the major sources of heavy metal contamination, especially Pb, is leaded petrol (Ozturk and Turkan, 1993).

Many plants accumulate trace elements in their aerial parts at much higher levels than in the soil supporting them (Markert, 1993; Baker *et al.*, 2000; Ma *et al.*, 2001; Ozturk *et al.*, 2008). Several herb and tree species have therefore been used for monitoring the levels of pollution in urban environments (Franzle *et al.*, 2008). Particle deposition on leaf surfaces may be affected by a variety of factors, including particle size and mass, wind velocity, leaf orientation, size, moisture level and surface characteristics. The deposited particles may be washed by rain into the soil, resuspended or retained on plant foliage. The degree of retention is influenced by weather conditions, the nature of the pollutant, plant surface characteristics and particle size (Ozturk *et al.*, 2008).

High levels of heavy metals in the soil do not always indicate similar high concentrations in plants. The extent of accumulation and toxic level depend on the plant species and heavy metal under observation (Sesli, 2004; Ozturk *et al.*, 2008).

One of the trees used in this connection is poplar; for example *Populus usbekistanica* ssp. *usbekistanica* cv. "Afghanica" (Yucel, 1996), *Populus nigra* (Djingova *et al.*, 1999, 2001), *Populus alba* (Madejon *et al.*, 2004) and *Populus deltoides x maximowiczii*, *P. x euramericana* (Sebastiani et al. 2004) and *Populus nigra* L. (*Berlizov et al.*, 2007). Earlier studies on the metal accumulations of traffic origin from Turkey have been discussed at length by Ozturk and Turkan (1993). The studies undertaken after this review include Yucel (1996), Aksoy and Ozturk (1996, 1997), Aksoy and Sahin (1999), Aksoy *et al.* (2000 a,b), Oncel *et al.* (2004), Baycu *et al.* (2006) and Yilmaz *et al.* (2007) on the plants of ruderal ecosystems.

To date there has been no such work on the Carolina poplar (*Populus x canadensis* Moench), a tree widely distributed in Turkey (Davis, 1982). We have selected this species to evaluate the accumulation of five trace elements in the bark, leaves and soil supporting these trees in the state of Zile Tokat in the Middle Black Sea region of Turkey.

Materials and Methods

Study area: The study area is located at the intersection point of the Middle Black Sea region and Central Anatolia, around the state of Zile-Tokat (Fig. 1). The area experiences a unique climate affected by oceanic and continental climates. The summers are dry and hot

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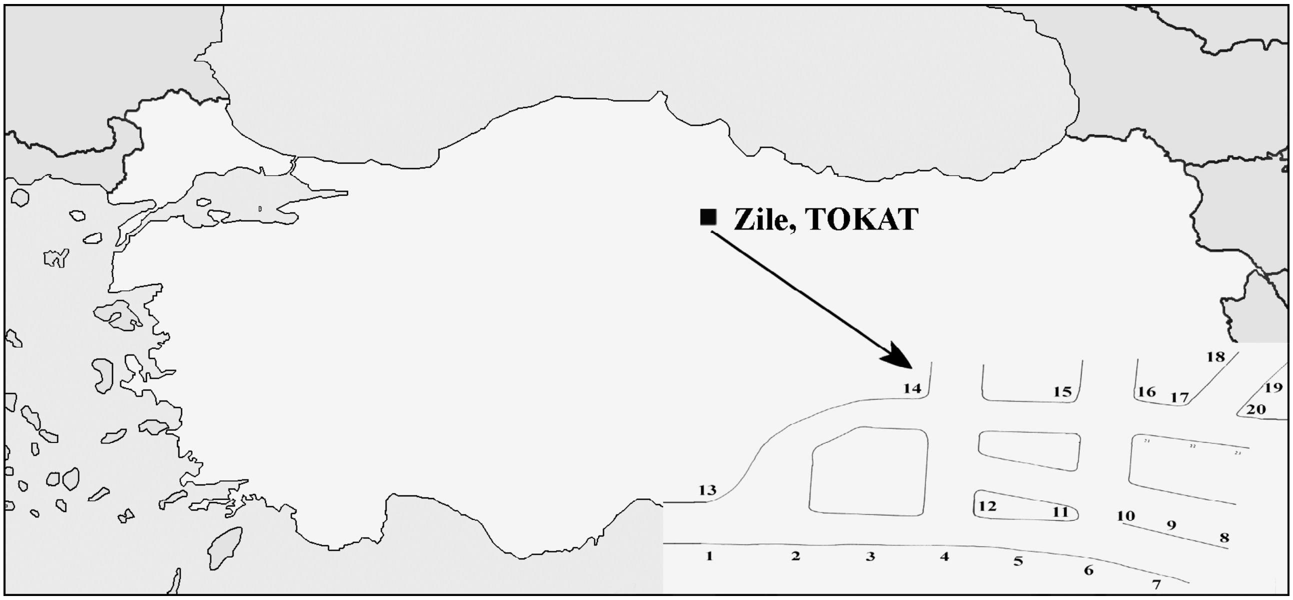

Fig. 1: Map of the study area and location of sampling sites

and the winters are cold. Precipitation in the form of heavy snowfall is a common feature of winter. Rain is generally common in spring or at the beginning of autumn. According to the data published by General Directorate of Turkish Sate Meteorological Service (GDTSMS, 2007) the annual avarage temperature lies around 10.29 °C, annual avarage maximum temperature around 17.12 °C and the annual average minimum temperature is around 3.78°C. The annual precipitation is 401.34 mm, whereas the potential evapo-transpration values are 79.24 mm and average wind speed is 1.66 m sec".

Sampling collection and analysis: Samples were collected from 23 locations (Table 1). The locations were selected on random basis depending the traffic load. Leaf samples of *Populus x canadensis* Moench were collected from twenty three sites at a height of 1-2 m from the ground level, whereas bark samples were collected from a height of 1 m from four different directions alongside the road. The traffic density in the area was around 2000 vehicles a day. The soil samples were taken from the top 10 cm at the base of trees used for leaf and bark collection with the help of a stainless steel trowel to avoid contamination.

The soil samples were air dried, passed through a 2-mm sieve and stored for analysis. The mature leaves of *P. x canadensis* (±150 g) were harvested during summer time, in the afternoon. The samples were then air dried for 12 hr followed by oven drying at 80°C for 24 hr. These were then stored in a glass dessicator with silica gel before grinding. The material was milled in a micro-hammer cutter and sieved through a 1.5 mm sieve. The cutter was washed after every grinding, first with absolute alcohol then with bi-distilled water to avoid any contamination. After homogenization, the plant and soil samples were placed in clean paper bags.

The soil and plant samples (1 g in weight) were ashed in a muffle furnace at 460°C, weighed and digested in concentrated HNO_3, evaporated to near dryness on a hot-plate and made up to volume with 1% HNO_3. The soils were digested in 10 ml Aqua Regia (1 part concentrated HNO_3 to 3 parts HCl, v/v) in a digestion tube (2 hr at 25°C, 2 hr at 60°C, 2 hr at 105°C and 3 hr at 125°C). All digested samples were centrifuged and made up to volume with 10% HNO_3. Lead, cadmium, zinc and copper concentrations were measured with an atomic absorption spectrophotometer (Perkin Elmer Model 1100), following the method given in detail by Aksoy and Ozturk (1996, 1997). A reference material was used with every batch (SRM 1547 peach leaves) to ascertain the accuracy of the method used. All data were subjected to *t*-test analysis using the SAS TTEST procedure (Anonymous, 1987).

The relationship between trace element accumulation and traffic density was examined by regression analysis.

Results and Discussion

The mean concentrations of trace elements in the unwashed leaves, bark and soil of *P. x canadensis* from different sites are presented in Tables 2-4.

Trace elements in leaves: The results presented in Table 2 show that Pb^{++} concentrations varied between 14.5-40.0 ppm and the average concentration of all sampling localities was 23.8 ppm. The lowest concentration was observed at locality 14 and the highest at locality 5. Cd^{++} concentration ranged between 0.5-1.5 ppm, the average of all localities being 1.37 ppm. Locality 4 had the lowest value and localities 3, 5, 6, 9 and 23 had higher values. The concentrations of Fe^{++} lied between 135-486 ppm, and the average concentration of all localities was 226.5. The lowest concentration was observed at locality 8 and the highest at locality 18. The concentrations of Cu^{++} ranged between 5.0-14.0 ppm, and the average of all localities was 9.4 ppm. The lowest concentration was observed at locality 3 and the highest at locality 4. The values of Zn^{++} concentration varied between 43-246 ppm and the average of all localities was 104.0 ppm. The lowest concentration was observed at

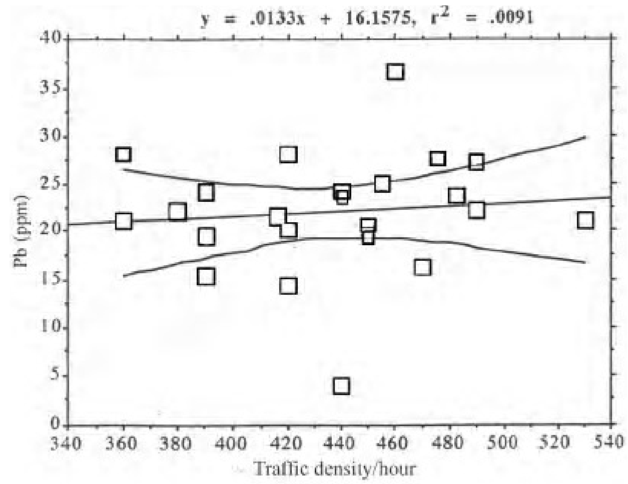

Fig. 2: Regression analysis showing correlations between Pb^{++} content in the leaves and traffic density (95% significant)

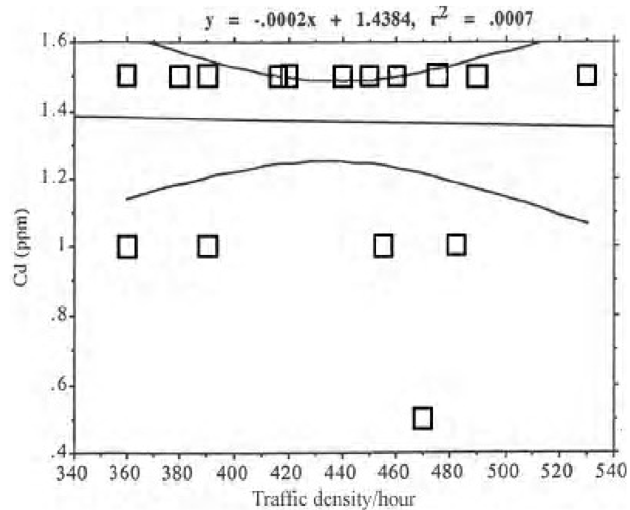

Fig. 3: Regression analysis showing correlations between Cd^{++} content in the leaves and traffic density (95% significant)

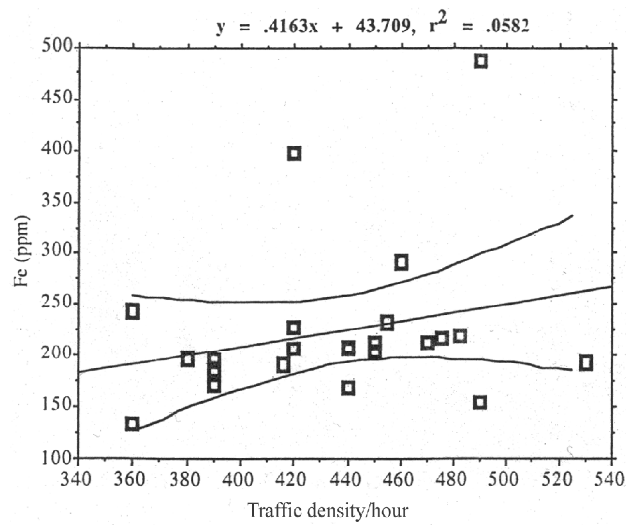

Fig. 4: Regression analysis showing correlations between Fe^{++} content in the leaves and traffic density (95% significant)

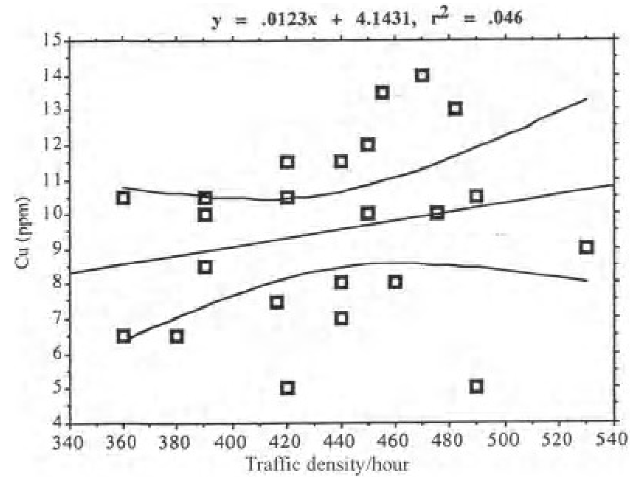

Fig. 5: Regression analysis showing correlations between Cu^{++} content in the leaves and traffic density (95% significant)

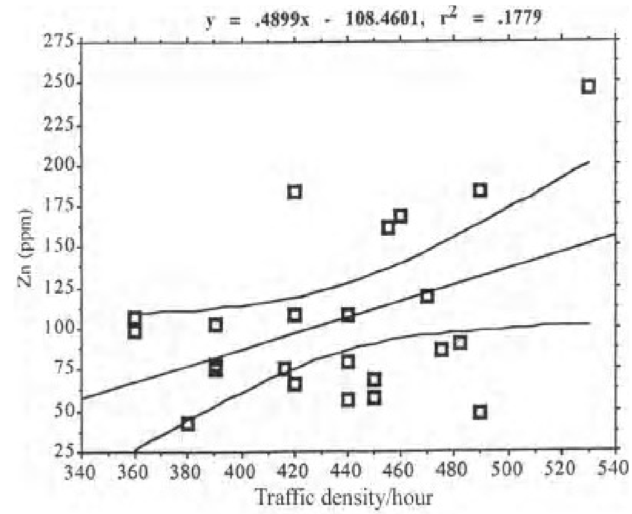

Fig. 6: Regression analysis showing correlations between Zn^{++} content in the leaves and traffic density (95% significant)

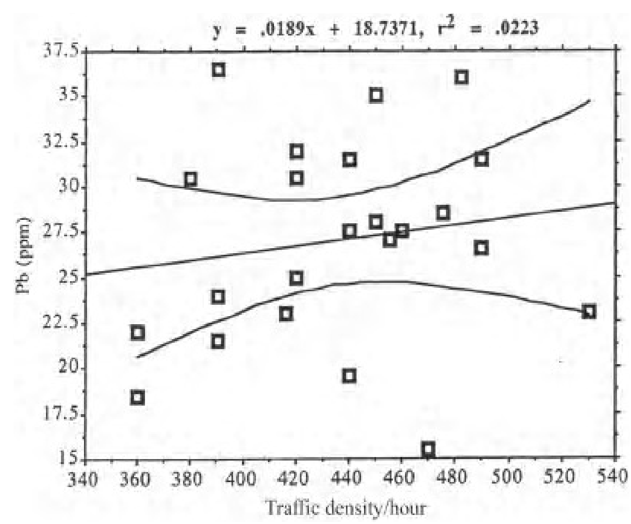

Fig. 7: Regression analysis showing correlations between Pb^{++} content in the bark and traffic density (95% significant)

Table - 1: The names of the localities

Locality	Name
1	Cekerek street (Hacilar vicinity 2. km)
2	Cekerek street (Hacilar vicinity 4. km)
3	Nato street (near D.S.I.)
4	Nato street (Zile center)
5	Amasya street (5. km)
6	Amasya street (2. km)
7	Amasya street (Zile exit)
8	Turhal street (6. km)
9	Turhal street (4. km)
10	Turhal street (1. km)
11	Turhal street (300 m)
12	Turhal street (Zile entrance)
13	Turhal street (Akyazi)
14	Zile city centre
15	Pazar street (1. km)
16	Pazar street (3. km)
17	Nato street
18	Istasyon street
19	Pazar street (5. km)
20	Pazar street (5. km)
21	Mehmet Akif Ersoy street
22	Stad street
23	Cekerek street (road margins)

Table - 2: Average trace element concentrations in the leaves of *Populus x canadensis* (ppm)

Locality	Pb^{++}	Cd^{++}	Fe^{++}	Cu^{++}	Zn^{++}
1	23.5	1.0	221	13.0	91
2	25.0	1.0	233	13.5	162
3	20.0	1.5	229	5.0	66
4	16.5	0.5	213	14.0	119
5	40.0	1.5	209	7.0	80
6	24.0	1.5	172	8.5	75
7	15.5	1.0	197	10.0	78
8	21.0	1.0	135	6.5	99
9	24.0	1.5	207	8.0	56
10	28.0	1.5	397	10.5	184
11	22.0	1.5	155	5.0	48
12	36.5	1.5	292	8.0	168
13	28.0	1.5	245	10.5	107
14	14.5	1.5	207	11.5	108
15	19.5	1.5	206	12.0	58
16	20.5	1.5	213	10.0	69
17	22.0	1.5	198	6.5	43
18	27.0	1.5	486	10.5	184
19	27.5	1.5	218	10.0	86
20	21.5	1.5	191	7.5	75
21	26.0	1.5	188	10.5	103
22	23.0	1.5	226	9.0	246
23	21.0	1.5	194	9.0	246
Average	23..8043	1.3696	226.5217	9.3913	104.043
St. Error	5.9137	0.2704	75.5248	2.5179	51.4908
Min.	14.5	0.5	135	5	43
Max.	40	1.5	486	14	246

locality 17 and the highest at locality 23 due to higher traffic density at locality 23 and lower at locality 17.

The regression analysis of the trace element contents in the leaves and their relation with traffic density revealed a positive correlation between traffic density and Pb^{++}, Fe^{++} and Cu^{++}, and a negative correlation between traffic density and Cd^{++}. No meaningful correlation was observed between traffic density and Zn accumulation (Fig. 2-6).

Trace elements in tree bark: The results presented in Table 3 show that Pb^{++} concentrations varied between 15.5-36.5 ppm, and the average concentration of all sampling localities was 26.9 ppm. The lowest concentration was observed at locality 4 and the highest at locality 6. Cd^{++} concentration varied between 1.5-2.0 ppm, with the average of all localities being 1.56 ppm. Localities 1-6,8,9,11-23 had lower values and localities 7,10 had higher values. The concentrations of Fe^{++} ranged between 39-575 ppm, and the average concentration of all localities was 226.5 ppm. The lowest concentration was observed at locality 7 and the highest at locality 1. The concentration of Cu^{++} ranged between 5.0-14.0 ppm and the average of all localities was 2.30 ppm. The lowest concentration was observed at locality 3 and the highest at locality 4. The values of Zn^{++} concentration varied between 40-1468 ppm, and the average of all localities was 104.1 ppm. The lowest concentration was observed at locality 4 and the highest at locality 10.

The regression analysis of the trace element contents in the bark and their relation with traffic density revealed a negative correlation between traffic density and Pb^{++} and a positive correlation between traffic density and Cd^{++}, Fe^{++}, Cu^{++} and Zn^{++} (Fig. 7-11).

Trace elements in soil: The results presented in Table 4 show that Pb^{++} concentration varied between 1.0-4.1 ppm, and the average concentration of all sampling localities was 2.73 ppm. The lowest concentration was observed at locality 9 and the highest at locality 23. Cd^{++} concentration was around 0.2 ppm for all sampling sites. The concentrations of Fe^{++} ranged between 0.6-1.8 ppm and the average concentration of all localities was 1.07 ppm. The lowest concentration was observed at locality 2 and the highest at locality 23. The concentration of Cu^{++} ranged between 0.1-0.9 ppm and the average of all localities was 0.3 ppm. The lowest concentration was observed at localities 10-12 and the highest at locality 19. The values of Zn^{++} concentration varied between 0.1-1.9 ppm, and the average of all localities was 0.44 ppm. The lowest concentration was observed at localities 2, 8 and 13 and the highest at locality 19.

Regression analysis of the trace element contents in the leaves and their relation with traffic density revealed a positive correlation between traffic density and Pb^{++}, Cu^{++}, Fe^{++} and Zn^{++}. No meaningful correlation was observed between traffic density and Cd^{++} accumulation (Fig. 12-15).

Various researchers have used different plant taxa as biomonitors to detect heavy metal pollution originating from traffic (Lau *et al.*, 2001; Li *et al.,* 2001; Monni *et al.*, 2001; Sawidis *et al.*,

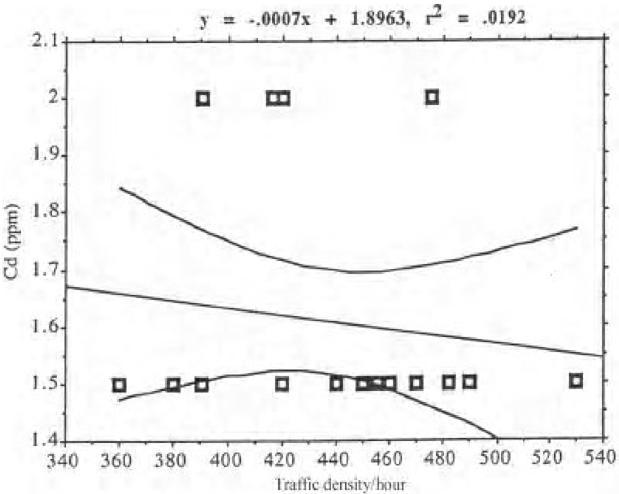

Fig. 8: Regression analysis showing correlations between Cd^{++} content in the bark and traffic density (95% significant)

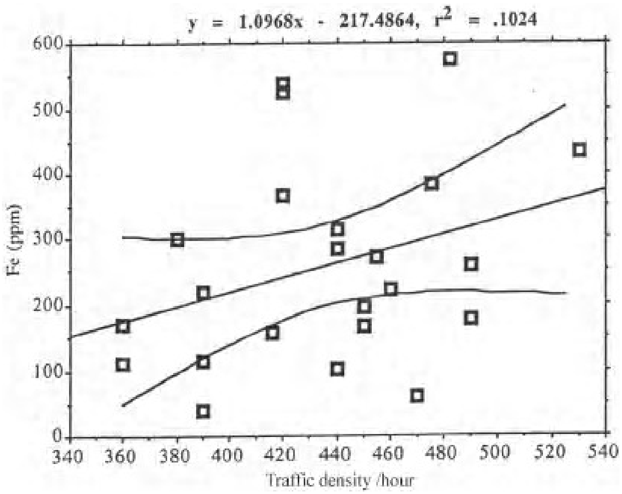

Fig. 9: Regression analysis showing correlations between Fe^{++} content in the bark and traffic density (95% significant)

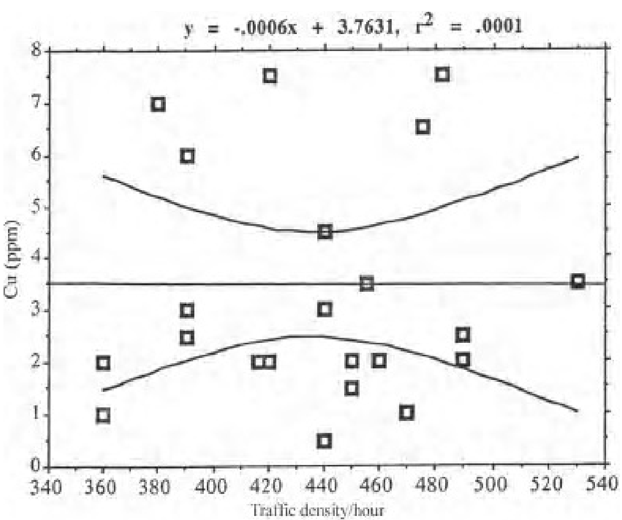

Fig. 10: Regression analysis showing correlations between Cu^{++} content in the bark and traffic density (95% significant)

2001; El-Hasan *et al.*, 2002; Abioye *et al.*, 2004; Aboal *et al.*, 2004; Madejon *et al.*, 2004; Sebastiani *et al.*, 2004; Tomasevic *et al.*, 2004; Lee *et al.*, 2005; Madejon *et al.*, 2006; Samecka-Cymerman *et al.*, 2006). In the last two decades, a lot of work have been carried out in Turkey (Turkan and Ozturk, 1989; Kutbay and Kilinc, 1991; Turkan and Henden, 1991; Ozturk and Turkan, 1993; Aksoy and Ozturk, 1996, 1997; Yucel, 1996; Aksoy and Sahin, 1999; Aksoy *et al.*,1999, 2000a, 2000b; Oncel *et al.*, 2004; Cicek and Koparal, 2004; Yilmaz and Zengin, 2004; Celik *et al.*, 2005; Aksoy and Demirezen, 2006; Baycu *et al.*, 2006; Coskun, 2006; Onder and Sukru, 2006; Cubukcu and Tuysuz, 2007; Yilmaz *et al.*, 2007). In all other researches heavy metal contents of samples changed according to traffic intensity and our results show similarities with previous studies. Samples collected near the highway contained high levels of heavy metals. A comparison of our findings with those of the workers cited above showed that in soil Madejon *et al.* (2004) measured very higher Pb, Zn, Cd and Fe concentration under *Populus alba* from surface and from deep soils. Sebastiani *et al.* (2004) also measured very high concntration level for Zn and Fe under *Populus euramericana*. In stems, Madejon *et al.* (2004) found lower concentrations for Pb and Zn from distant areas from highways and obtained results for Cd which are higher near highways and lower distant from highways than our results and in leaves Cicek and Koparal (2004) found higher Pb levels near highways and lower results distant from highways than ours. Their Zn measurements were lower than our results whereas Cd and Fe concentrations were higher. Madejon *et al.* (2004) found lower Pb accumulation than all our results. Zn concentrations are higher, Cd and Fe concentrations are lower. Sebastiani *et al.* (2004) found very high concentrations in Populus deltoides maximowiczii leaves than our results. Yucel (1996) found higher Zn concentrations in Populus x euramericana and lower Pb and higher Cd levels for Populus usbekistanica subsp. usbekistanica. Zn levels are higher than our results near highways but distant places contain lower concentrations. Bereket and Yucel (1990) found lower concentrations for Pb and higher Zn and Cd concentrations in Populus nigra ssp. nigra compared to our results. Tomasevic *et al.* (2004) found lower Pb, Zn, Cd concentrations for Populus sp. Cicek and Koparal (2004) found lower Zn and Fe concentrations for *Populus nigra* but Cd concentrations are higher than our results near highways and lower at distant places.

In the case of leaves there was a positive correlation between traffic density and the amount of Pb^{++}, Fe^{++} and Cu^{++}, and a negative one with Cd^{++} and Zn^{++}. All our results showed a possitive relation with traffic density except for Cd. When these results were evaluated, a meaningful result was obtained between Pb concentrations in soil, bark and leaves and traffic density. Although some of the stations that were investigated had high concentrations of certain metals and low concentrations of other ones, when they were correlated with traffic density no meaningful result was obtained. In other words, the deposition of these metals probably indicates the accumulation of dust raised by motor vehicles and other human activities.

The higher Pb content in urban roadside soil and plant samples is due to traffic density, which is considered as one of

Table - 3: Average trace element concentrations in the bark samples of *Populus x canadensis* (ppm)

Locality	Pb^{++}	Cd^{++}	Fe^{++}	Cu^{++}	Zn^{++}
1	36.0	1.5	575	7.5	152
2	27.0	1.5	272	3.5	260
3	30.5	1.5	524	7.5	191
4	15.5	1.5	60	1.0	40
5	27.5	1.5	103	0.5	125
6	36.5	1.5	116	6.0	141
7	21.5	2.0	39	2.5	224
8	18.5	1.5	170	2.0	108
9	31.5	1.5	314	3.0	233
10	32.0	2.0	538	7.5	1468
11	31.5	1.5	259	2.5	126
12	27.5	1.5	222	2.0	107
13	22.0	1.5	111	1.0	96
14	25.0	1.5	366	2.0	172
15	28.0	1.5	166	2.0	84
16	35.0	1.5	196	1.5	123
17	30.5	1.5	300	7.0	391
18	26.6	1.5	176	2.0	98
19	28.5	1.5	383	6.5	165
20	23.0	1.5	159	2.0	128
21	24.0	1.5	219	3.0	216
22	19.5	1.5	285	4.5	206
23	23.0	1.5	433	3.5	126
Average	26.9565	1.5652	253.3043	3.5	216.5217
St. Error	5.6042	0.1722	154.6308	2.316	282.5644
Min.	15.5	1.5	39	0.5	40
Max.	36.5	2	578	7.5	1468

Table - 4: Average trace element concentrations in the soil of *Populus x canadensis* (ppm)

Locality	Pb^{++}	Cd^{++}	Fe^{++}	Cu^{++}	Zn^{++}
1	2.4	0.2	0.7	0.2	0.2
2	2.2	0.2	0.6	0.2	0.1
3	3.5	0.2	0.7	0.2	0.2
4	2.3	0.2	0.8	0.3	0.3
5	2.8	0.2	1.3	0.3	0.2
6	3.2	0.2	0.9	0.2	0.3
7	1.0	0.2	0.8	0.3	0.2
8	2.6	0.2	0.9	0.2	0.1
9	1.0	0.2	0.9	0.2	0.2
10	3.2	0.2	1.0	0.1	0.2
11	3.9	0.2	0.9	0.1	0.2
12	1.6	0.2	0.7	0.1	0.2
13	3.2	0.2	1.2	0.2	0.1
14	2.7	0.2	1.2	0.3	0.5
15	4.0	0.2	1.4	0.4	1.3
16	2.9	0.2	1.3	0.4	1.3
17	2.9	0.2	1.4	0.5	0.5
18	3.5	0.2	1.0	0.3	0.4
19	2.7	0.2	1.7	0.9	1.9
20	2.9	0.2	1.2	0.7	0.8
21	2.9	0.2	1.4	0.2	0.5
22	1.4	0.2	0.9	0.2	0.2
23	4.1	0.2	1.8	0.2	0.2
Average.	2.7348	0.2	1.0739	0.2913	0.4391
St. Error	0.8648	0	0.3264	0.1905	0.4629
Min.	1	0.2	0.6	0.1	0.1
Max.	4.1	0.2	1.8	0.9	1.9

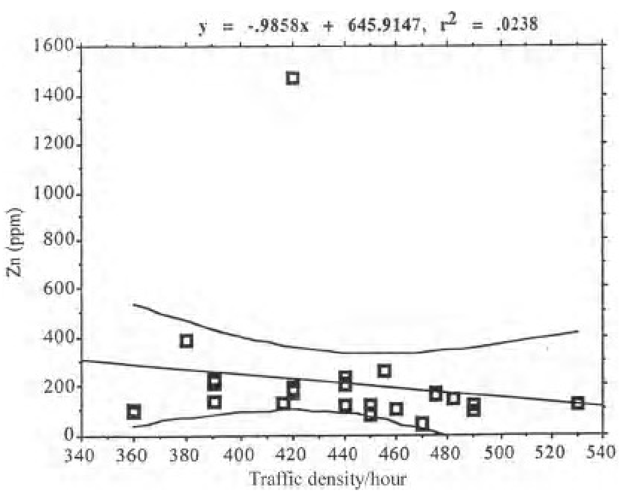

Fig. 11: Regression analysis showing correlations between Zn^{++} content in the bark and traffic density (95% significant)

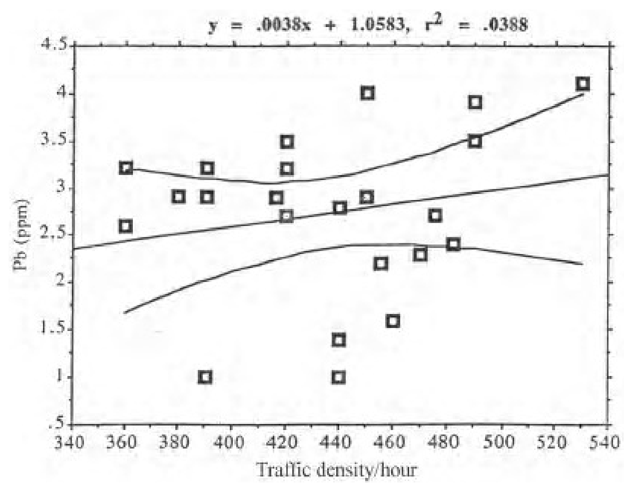

Fig. 12: Regression analysis showing correlations between Pb^{++} content in the soil and traffic density (95% significant)

the major sources of Pb contamination as shown by many investigations in different countries (Aksoy and Ozturk, 1997). Our results showed that bioaccumulation of heavy metals occurs mostly in the upperground parts, but exceptionally in Zn bioaccumulation is higher in belowground parts and Cd concentrations of the areas with higher traffic density are slightly higher.

The bark of trees has been used for passive biomonitoring (Bohn *et al.*, 1998). In the bark samples a positive correlation was observed between traffic density and Pb^{++}, and a negative one with the amount of Cd^{++}, Fe^{++}, Cu^{++} and Zn^{++}. A positive correlation was determined between traffic density and the amount of Pb^{++}, Fe^{++}, Cu^{++} and Zn^{++} in soil. However, the amount of Cd^{++} was 0.2 ppm and no relationship between Cd^{++} and traffic density was observed.

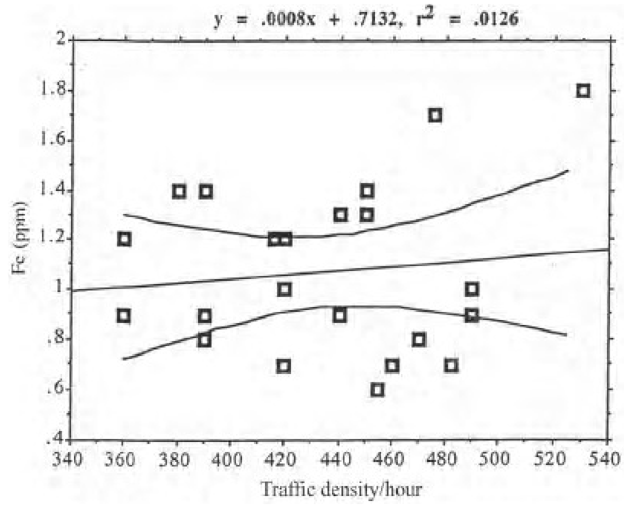

Fig. 13: Regression analysis showing correlations between Fe^{++} content in the soil and traffic density (95% significant)

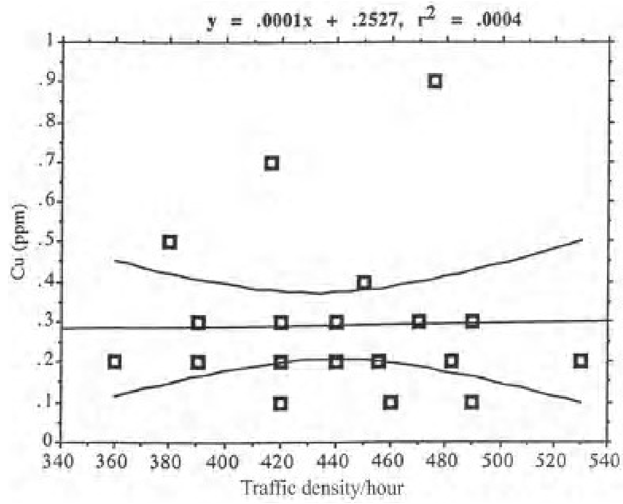

Fig. 14: Regression analysis showing correlations between Cu^{++} content in the soil and traffic density (95% significant)

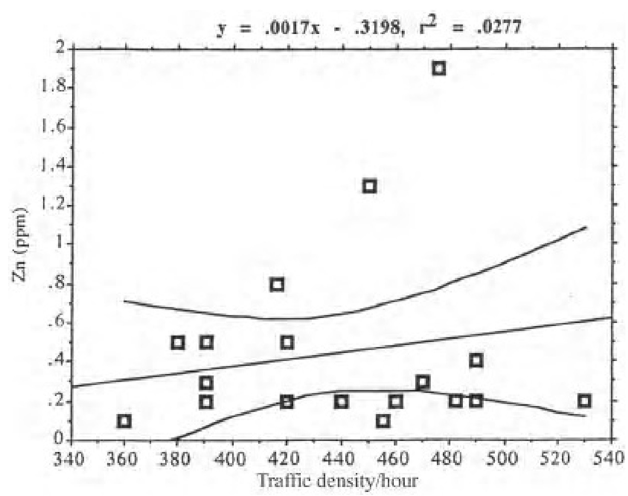

Fig. 15: Regression analysis showing correlations between Zn^{++} content in the soil and traffic density (95% significant)

Yucel (1996) indicated that Cu^{++} and Zn^{++} contamination could be higher in areas with no traffic, proving that these two metals are not the result of traffic pollution. Madejon *et al.* (2004) indicated that the accumulation of Cd^{++} and Zn^{++} in plant parts showed a positive correlation with soil concentrations. Our results for Cd^{++} and Zn^{++} levels had the same trend and similarly to Madejon *et al.* (2004), among plant organs, leaves accumulated a higher concentration of trace elements.

In conclusion, heavy metals play an important role in the environmental pollution. The control measures for this are to carry out their periodic control. This can be done by analyzing soils and plant species at regular intervals (Ozturk *et al.*, 2008). Monitoring of heavy metals in the ecosystems surrounding us with the help of soils and plants gives positive results due to their immobility. Some species are accumulators or even hyperaccumulators, while others are excluders. The disadvantage with the plant biomonitors is that their reaction not only depends on the quantity of the substance to be monitored but also other morphological features of plant species as well as soil type, nutrient status and moisture, nutrient status of the soil and climatic parameters. Phytoremediation is a new technology employed for removing excessive toxic elements from the soil (Glass, 2000; Blaylock and Huang, 2000; Babaoglu *et al.*, 2004). Our results show clearly that lead content in plants and soil along motor roads is increasing. This increase is higher on the roads with a heavy traffic load. We suggest that leaded fuels should be prohibited and appropriate plant species could be used as a barrier alongside roads to reduce the aerial deposition caused by emissions from motor vehicles.

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