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Air borne heavy metal pollution of *Cedrus libani* (A. Rich.) in the city centre of Konya (Turkey)

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Abstract

The contents of heavy metal accumulated by air pollution in the cedar tree needles from the green area of Konya city centre were measured by chemical analyses. The needle samples were collected from two types of trees (about 10–15 and 20–25-years-old trees) from eight different pollution regions for two different sampling periods. Results of sulphur dioxide and particle matter analyses were used for measurement of air pollution effect on accumulation of heavy metals in the vegetation. Contents of heavy metals (Pb, Cu, Zn, Co, Cr, Cd and V) were determined for sampling periods, tree ages and sampling places. Results of the present study showed that accumulations of heavy metals in the old trees were generally higher than those of young trees. Similarly, heavy metal contents of needles collected in spring 2004 were higher than those of needles collected in autumn 2003. Accumulation of heavy metals via sulphur dioxide pollution and particle matter originated from usage of low quality fossil fuels, which might affect the living organisms in the city centre. On the other hand, Pb levels in the samples from Karatay Industry Park (3.53 ppm in 2004) showed that people are health living around the industry, and heavy traffic area is under risk. According to the other sampling areas, the chromium levels were also very high around the Chrome–Magnesite Factory Garden (87.15 ppm in 2004); it could be a toxic risk for people working around the factory. The heavy metal levels obtained from the other samples were not as high a risk level for the living organisms in the sampling areas.

Keywords: Air pollution; Sulphur dioxide; Heavy metals; Cedar tree; Konya city; Health

1. Introduction

Increasing industrialisation 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 humans as well as to plants. 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

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will be more reliable than that obtained from direct determination of the pollutant concentrations in air for a short period. Hence, analysing plant tissues can give better results in terms of sensitivity and reproducibility (Lau and Luk, 2001). Levels of environmental pollution in some areas from Turkey are alarmingly high and it is a national concern. Air pollution is the most important problem in the main city centres. Konya is one of the heaviest air-polluted cities in the winter period of the year (Onder and Gür, 2000; Dursun and Söyleyici, 2001). The sulphur dioxide concentration increase on some winter days over 200 mg m^{-3}, and also particle matter in the air is parallel to SO_2 concentration on the same days, due to usage of low-quality fossil fuels in heating systems. Power plants, refineries and domestic usage of fuels are major contributors, and additional SO_2 is released into the air when certain ores of nickel, copper, lead and iron are smelted. Air pollution is aesthetically offensive and can affect human health as well as vegetation, plants and micro-organisms (Boddy et al., 1994; Dursun et al., 2002a).

The emission of toxic substances in the environment has been spread from industrialised countries. Many industrial plants and also heavy traffic may produce heavy metal into the atmosphere. Traffic pollutants include potentially toxic metals for health like lead, cadmium and zinc (Viard et al., 2004). However, many sites around the world remain contaminated, representing a risk to humans and other living organisms. Heavy metals are among the pollutants that need to be removed from such contaminated sites. Several heavy metals, such as Pb, Co, Cd, Cu and Cr, are considered hazardous contaminants that can accumulate in the human body, with a relatively long half-life. It has been stated that, e.g., Cd has a half-life of 10 yr once in the human body (Salt et al., 1995). Additionally, some species of Cd, Cr and Cu have been associated with health effects ranging from dermatitis to various types of cancer (Das et al., 1997). Time-series analyses, conducted in many industrial countries, have consistently shown that short-term changes in air pollution levels are associated with changes in daily death rates (Stieb et al., 2002). Heavy metals cause serious environmental risks and, therefore, its effect has been examined extensively.

Uptake of elements into plants can happen via different ways. The elements can be taken up via roots from the soil and transported to the leaves. Trace elements may be taken up from the air, or by precipitation directly via the leaves. In addition, some plants even exhibit ion-exchange properties. Once deposited on the leaf surface some elements may also be taken up into the leaf via the stomata (Reimann et al., 2001). Phytoremediation, the use of plants to restore polluted sites, has recently become a tangible alternative to traditional methodologies (Glass, 2000). It has been established that certain wild and crop plant species have the ability to accumulate elevated amounts of toxic heavy metals (Blaylock and Huang, 2000; Reeves and Baker, 2000; Ernst et al., 2000). However, researchers all over the world are researching new plant species susceptible to be used in phytoremediation. Field bindweed, *Convolvulus arvensis* L., a prostrate perennial plant, drought resistant, with a deeply penetrating taproot that grows mostly in dry soils (Hickey and King, 1988), has been identified among the plants that grow wildly in the multi-metal-contaminated soil of Spain and Poland (Del Rio et al., 2002).

There are many investigations on Pb, Cd, Hg and other heavy metal levels in air, and their toxic effect on the plant. However, there is no more information of toxic levels of these heavy metals and limits on the plant (Eraslan, 1988). Researchers showed that Al has toxic effect on numerous fungi in laboratory conditions at very low concentrations, and this effect increased with the increasing acidity of the medium (Dursun et al. 2002b). Dry deposition of heavy metals and acidic compounds on the plants were increasing in the dry period of year, and a higher effect was detected after precipitation (Dursun et al., 1996a). Deposited materials on the leaves and needles, which is an important part of trees for photosynthesis, had effects on chlorophyll, cell membrane and stomas, and reduced the plant's development. Because of dry and wet deposition, the growth of main and side buds stops, leaving colour to fade and some parts of trees to get dry. These types of changes reduce the resistance of trees to drought, frost, insects and fungi (Eraslan, 1988; Shanker et al., 2005).

The removal of metals by biosorption and the mechanisms of biosorption have been discussed previously, and it has been reported that biosorption may be classified as being: extracellular accumulation/precipitation, cell surface sorption/precipitation and intracellular accumulation (Veglio and Beolchini, 1997), and can occur by complexation, co-ordination, chelation of metals, ion exchange, adsorption and micro-precipitation (Wang et al., 1996).

In recent years, it has been shown that lead levels in soil and vegetation have 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). Recently, 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). The reason being, the lead content of petrol sold to the consumer throughout the county is quite high. As city population ever increases, 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).

Botanical materials such as fungi, lichens, tree bark, tree rings and leaves of higher plants have been used to detect pollution. The monitoring of the levels of atmospheric trace metallic concentration by using different types of biological monitors and various vegetation have been reported by different researchers (Rao and Dubey, 1992; Morselli et al., 2004). Heavy metals emitted into the environment in different ways, i.e. transportation, industry, fossil fuels, agriculture and other human activities (Aksoy et al., 2000a). The most economical and reasonable method for monitoring the heavy metal levels in the atmosphere is using vegetation, Scots pine (Yılmaz and Zengin, 2003), acacia (Aksoy et al., 2000a) and other plants (Aksoy et al., 2000b), and other organisms such as fishes (Rashed, 2001) have also been used for biomonitoring.

The aim of this study was to investigate the levels of heavy metals (Pb, Cu, Zn, Co, Cr, V and Cd) in the cedar tree needles grown near the main road and industrialised areas in Konya city (Turkey) polluted by burning fossil fuel emissions, heavy traffic conditions and industries.

2. Materials and methods

2.1. Experimental site

The study area (Konya city) is located in the central region of Turkey. Konya city has three central districts which are Selçuklu, Karatay and Meram. Cedar tree (*Cedrus libani* A. Rich.) is one of the dominant tree species in the green area of Konya city. For this reason, the needles obtained from cedar trees were used in this investigation. The samples were collected from eight sampling points, each of which was about a 50-m-diameter circle area in the Konya city centre, four sampling points in residential areas, three in industrial areas (Fig. 1). The coordinates of the sampling points were determined using Macellan Model GPS. The locations of sampling points are Alaeddin Hill Park (coordinate—455329E–419199N), Anıt Place (4554486E–419131N), Cement Factory Garden (459249E–419927N), University Campus (457110E–420933N), Chrome–Magnesite Factory Garden (448271E–418713N), Karatay Industry Park (456235E–419524N), Meram Area (456444E–41918N) and Sugar Factory Garden (453237E–419243N) in the Konya city centre. Some of the sampling points were in the residential area, and others were close to the industrial facilities. The sampling points are marked on Fig. 1.

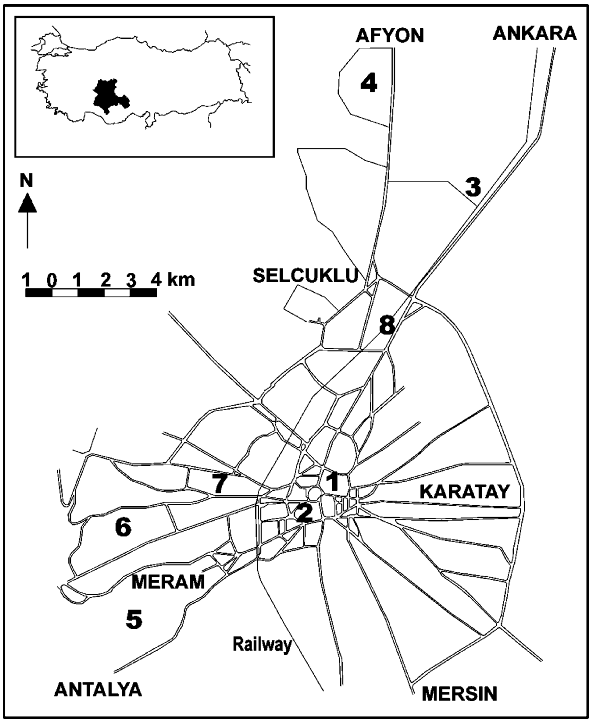

Fig. 1. Locations of sampling points in Konya city centre: (1) Alaeddin Hill Park, (2) Anıt Place, (3) Cement Factory Garden, (4) Selcuk University Campus (5) Chrome–Magnesite Factory Garden, (6) Meram Area, (7) Sugar Factory Garden, (8) Karatay Industry Park.

2.2. Collection and preparation of samples

The needle samples from cedar trees (*Cedrus libani* A. Rich.) were collected from the sampling points given above, in December 2003 and April 2004. Cedar trees are widespread in Konya city. The needle samples were collected from the two types of trees which are young trees (about 10–15-year-old) and old trees (about 20–25-years-old). All of the trees were determined according to the documents obtained from the Konya Municipality and the factories. The needle samples were obtained from each part of the tree and then were homogeneously mixed. The needle samples were supplied from the trees according to the main wind direction (i.e. the highest wind speed). The samples were collected into clean cellulose bags separately, and were brought to the laboratory on the same day. After removing any traces of soil and other plant materials in the laboratory, the samples were carefully washed three times with demineralised water to remove adhering particles (Babaoğlu et al., 2004), and were then oven-dried at 70 °C for 48 h before the dry matters were weighed. The samples (0.5 g) of finely ground needles were digested with concentrated HNO_3 in a microwave system (CEM). The metals in the extracts were analysed by inductively coupled plasma-atomic emission spectrometry (ICP-AES), Varian–Vista model; Nyomora et al., 1997) with three replicates. Used metal standards were provided from Merck, Germany.

2.3. Statistical analysis

The analysis of variance (ANOVA) was used to compare each heavy metal (Pb, Cu, Zn, Co, Cr, V and Cd), each sample collection location (*A*), needle age (*B*) and AxB interaction in years 2003 and 2004, separately. *F* is a parameter (i.e. *A*, *B* and AxB) in the level of 1% and 5%. If *F* is a statistically significant aspect of any heavy metal, the Duncan Test was done on these mean values. ANOVA and Duncan's multiple range tests were performed using the MSTAT-C P.C. package programme.

3. Results

SO_2 and particle matter (PM) contents were measured at four sampling points in Konya city centre by Konya Health Organisation and the results were regulated by the Konya Environment and Forest Organisation, whose monthly means are given in Table 1. Both SO_2 and PM contents were over $100\,mg\,m^{-3}$ in the winter period between 2002–2004, but their contents decreased by about $10\,mg\,m^{-3}$ in the summer period. The increase of air pollution was due to the usage of low-quality coal for heating systems in the winter period, because air temperature in the city was sometimes lower than −20 °C. The winter period lasts about 7 month a year in Konya. Air pollution from traffic was also very important for the city centre where most of the pollution resulted from traffic in the summer period.

Table 1
Monthly mean atmospheric sulphur dioxide (SO_2) and particle matter (PM) concentration measured at four sampling station in the city centre of Konya[a]

Parameter	SO_2 ($mg\,m^{-3}$)			Particle matter ($mg\,m^{-3}$)		
Sampling period	2002	2003	2004	2002	2003	2004
January	113	83	113	108	125	129
February	96	65	87	121	53	63
March	63	72	69	41	51	55
April	40	47	31	46	38	27
May	24	16	20	27	16	16
June	18	16	17	20	11	13
July	19	16	17	24	12	11
August	17	15	17	19	11	11
September	18	20	16	29	19	13
October	29	39	22	53	34	25
November	80	75	34	135	100	75
December	78	64	60	143	98	135
Annual mean	50	44	42	64	47	48

[a]Data were obtained from Konya Environment Office.

In this investigation, the effect of environmental pollution on deposition of heavy metals on trees was investigated by analysing seven heavy-metal (Zn, V, Cr, Cu, Pb, Co and Cd) contents of cedar tree needles obtained from the young and old trees, separately. The samples were collected in December 2003 and April 2004. Both types of needles (i.e. young and old types) were collected from eight different sampling points (Fig. 1). Mean contents of the metals measured in 2003 and 2004 years and Duncan's test are given in Tables 2 and 3. Results of the variance analysis (ANOVA) are also given in Table 4. Variance analyses for any metal showed that there were significant differences ($p<0.05$ or $p<0.05$) between *A*, *B* and AxB interaction.

As is seen in Table 4, there were significant differences ($p<0.01$) between the sampling points (*A*) for both sampling years for lead contents. However, there was not a significant difference

Table 2
Heavy metal content (ppm) in the two types of cedar tree needles collected from eight sampling points in Konya city centre in December 2003 and Duncan groups[a]

Sampling points	Needles types	Pb	Cu	Zn	Co	Cr	V	Cd
Alaeddin	Yang tree	2.0530	1.4753	11.4248	0.2673	4.1191	7.9570	0.2181
Hill Park	Old tree	1.0620	1.1366	9.8867	0.3821	10.5802	9.5473	0.1596
Mean		1.5570ab	1.3060e	10.656cd	0.3250abc	7.350ab	8.752d	0.1890
Anıt Place	Yang tree	1.0062	1.6665	10.1350	0.4513	2.0638	7.8672	0.1826
	Old tree	2.2080	2.4899	11.0874	0.2064	4.4427	15.2402	0.1826
Mean		1.6070ab	2.078cd	10.603d	0.3290abc	3.2530b	11.554c	0.1830
Cement Fact. Garden	Yang tree	0.8697	2.2750	17.6669	0.4814	3.3792	18.8255	0.1230
	Old tree	0.7844	2.1249	17.2298	0.3943	3.3747	18.6052	0.1396
Mean		0.8270b	2.200cd	17.449ab	0.4380a	3.3770b	18.715a	0.1310
University Campus	Yang tree	1.0122	1.9854	9.3248	0.4004	3.5788	12.2713	0.1872
	Old tree	0.5777	2.3130	14.6313	0.4182	3.4233	14.9292	0.0840
Mean		0.7950b	2.1490cd	11.978cd	0.409ab	3.5010b	13.600b	0.1360
Chr-Magn. Fact. Garden	Yang tree	1.0838	1.4903	8.0524	0.4212	6.4801	20.0482	0.1040
	Old tree	1.8458	3.6300	12.2155	0.0100	54.9399	19.3806	0.0926
Mean		1.4650b	2.5600c	10.134d	0.211bc	30.711a	19.714a	0.0980
Meram Area	Yang tree	1.1604	1.5774	14.8881	0.4077	2.4240	17.9737	0.2063
	Old tree	1.8258	2.0298	12.9673	0.3161	5.7230	22.9278	0.0918
Mean		1.4930ab	1.8040de	13.928bc	0.362abc	4.0730b	20.451a	0.1490
Sugar Factory Garden	Yang tree	1.7555	6.8881	17.4776	0.0617	8.7537	13.8271	0.1326
	Old tree	1.5692	4.8962	18.3073	0.2814	3.2817	14.4641	0.1108
Mean		1.6620ab	5.8920a	17.892ab	0.172c	6.0180b	14.146b	0.1220
Karatay Industry Park	Yang tree	2.9856	3.6250	26.5781	0.3097	3.6074	11.2826	0.1996
	Old tree	2.9721	3.8842	14.6914	0.2516	5.4877	8.8683	0.1689
Mean		2.9790a	3.7550b	20.635a	0.2810abc	4.5480b	10.075cd	0.1840
Sampling point mean	Yang tree	1.4915	2.6228	14.4434	0.3501	4.3001	13.8108	0.1692
	Old tree	1.6056	2.8131	13.8771	0.2825	11.4066	15.4953	0.1287
General mean		1.5486	2.7179	14.1602	0.3163	7.8534	14.6531	0.1490

[a]Within columns, means followed by the same letter are not significantly different by ANOVA-protected Duncan's multiple range test ($p<0.01$).

($p>0.05$) between lead contents of young and old tree needles (*B*) for both sampling periods. As a mean of young and old trees, the maximum Pb content was 2.98 ppm for needles of cedar tree from Karatay Industry Park, and other contents followed Sugar Factory Garden (1.66 ppm), Anıt Place (1.61 ppm), Alaeddin Hill Park (1.56 ppm), Meram Area (1.49 ppm), Chrome–Magnesite Factory Garden (1.47 ppm), Cement Factory Garden (0.83 ppm) and Selcuk University Campus (0.80 ppm) in the samples of 2003. In the second year (2004) of this investigation, as seen in the 2003 sampling, Pb content was the highest at Karatay Industry Park (3.53 ppm) with similar order to other places, and the lowest was at Selcuk University Campus (0.88 ppm) (Table 3 and Fig. 2). Accumulation of Pb in the needles of old trees was higher than in young trees in both sampling periods, 2003 and 2004 (Tables 2 and 3; Fig. 2).

Analysis of variance for Cu content in needle samples indicated that there were significant differences ($p<0.01$ or $p<0.05$) between all the

Table 3
Heavy metal content (ppm) in the needles of cedar tree collected from eight sampling points in Konya city centre in April 2004 and Duncan groups[a]

Sampling point	Needles types	Pb	Cu	Zn	Co	Cr	V	Cd
Alaeddin Hill Park	Yang tree	2.5264	2.2019	26.8173	0.1908	8.2273	10.8702	0.0888
	Old tree	2.3403	1.9216	16.6579	0.1132	7.9254	10.5449	0.0165
Mean		2.433ab	2.062bc	21.738	0.152bc	8.076b	10.708d	0.053
Anıt Place	Yang tree	1.1641	1.8761	18.6490	0.2857	5.3918	10.8902	0.0872
	Old tree	2.2943	2.9847	24.8520	0.1865	9.5609	17.5653	0.0431
Mean		1.729ab	2.430abc	21.751	0.236ab	7.476b	14.228d	0.065
Cement Fact.Gard.	Yang tree	1.2248	4.1718	29.0679	0.0948	11.5941	68.8702	0.0179
	Old tree	0.7970	2.6534	21.8266	0.1414	8.6037	38.3954	0.0934
Mean		1.013b	3.413abc	25.447	0.118bc	10.102b	53.633a	0.056
University Campus	Yang tree	0.9029	4.9583	35.5783	0.0752	4.6444	14.5496	0.0365
	Old tree	0.8728	2.0950	22.2584	0.1589	5.2958	32.6424	0.0852
Mean		0.888b	3.527abc	28.918	0.117bc	4.970b	23.596bc	0.061
Chr-Magn. Fact. Gar.	Yang tree	1.3438	1.7235	17.6084	0.3163	10.4258	26.3843	0.1411
	Old tree	3.4712	4.6768	38.9888	0.0110	87.1513	27.4085	0.1088
Mean		2.407ab	3.200abc	28.299	0.159abc	48.789a	26.896b	0.125
Meram Area	Yang tree	1.0690	1.9262	23.2819	0.4682	5.1403	34.6779	0.0563
	Old tree	1.9518	1.9647	17.7273	0.3046	11.2675	32.1685	0.0805
Mean		1.510ab	1.945c	20.505	0.386a	8.204b	33.423b	0.069
Sugar Fac. Garden	Yang tree	1.2536	3.9840	20.1861	0.2783	5.1643	18.8683	0.1150
	Old tree	2.0985	6.6016	32.2162	0.0930	10.5124	16.1097	0.1027
Mean		1.676ab	5.343a	26.201	0.186abc	7.838b	17.489cd	0.109
Karatay Ind. Park	Yang tree	3.9943	5.2849	33.1397	0.0260	9.1534	10.4532	0.1808
	Old tree	3.0645	4.4468	27.0853	0.0112	8.9217	13.7565	0.1106
Mean		3.529a	4.903ab	30.113	0.019c	9.038b	12.105d	0.146
Sampling point mean	Yang tree	1.6848	3.2659	25.5411	0.2169	7.4677	24.4457	0.0905
	Old tree	2.1113	3.4181	25.2016	0.1275	18.6548	23.5739	0.0801
General mean		1.8981	3.3420	25.3713	0.1722	13.0612	24.0098	0.0853

[a]Within columns, means followed by the same letter are not significantly different by ANOVA-protected Duncan's multiple range test ($p<0.01$).

parameters (A, B and AxB), except between samples ages ($p>0.05$) for the 2004 sampling (Table 4). The highest Cu contents for two sampling periods were detected in the needle samples from the Sugar Factory Garden trees (5.89 ppm and 5.34 ppm in 2003 and 2004 years, respectively). Accumulation of Cu in the needles of older age trees were higher than in younger tree needles for the 2 sampling years, and Cu values in 2004 were also higher than in 2003 year's sampling (Tables 2 and 3).

Zinc contents in the needles had the highest values in the samples from Karatay Industry Park (20.64 ppm in 2003 and 30.11 ppm in 2004; Tables 2 and 3, Fig. 2). There was a significant difference ($p<0.01$) between the Zn contents of different sampling points in the 2003 year sampling (not in 2004), and significant interaction between sampling places (A) and tree ages (B) for both sampling periods (Table 4). The overall mean contents of Zn were 14.16 and 25.37 ppm in the 2003 and 2004

Table 4
Results of the analysis of variance (ANOVA)

Sampling period	Sources of variation	Degrees of freedom (DF)	Mean of squares						
			Pb	Cu	Zn	Co	Cr	V	Cd
2003	Sampling location (*A*)	7	2.709**	12.863**	96.538**	0.051**	524.063**	122.120**	0.007
	Needles age (*B*)	1	0.158	0.434*	3.819	0.057**	605.919**	36.281**	0.020
	(AxB) interaction	7	0.766	2.025**	41.167**	0.060**	436.327**	15.223**	0.003
	Error	32	0.319	0.071	1.702	0.007	24.397	0.610	0.006
	General	47	0.738	2.275	21.749	0.023	172.539	21.643	0.006
2004	Sampling location (*A*)	7	4.492**	9.360**	80.847	0.069**	1263.226**	1227.023**	0.007
	Needles age (*B*)	1	2.186	0.204	1.383	0.099**	1501.605**	9.116	0.020
	(AxB) interaction	7	1.483	5.908**	222.853**	0.026**	1066.866**	25.573**	0.003
	Error	32	0.822	1.387	52.493	0.006	22.118	11.065	0.006
	General	47	1.496	3.223	81.001	0.020	394.046	232.620	0.006

** and * Indicate statistical differences between the treatments at $p<0.01$ and $p<0.05$, respectively.

samplings, respectively, the increase of Zn content was about 80% after the winter period in year 2004.

As seen in the variance analysis between the Co contents in Table 4, there were statistically significant differences ($p<0.01$) for all investigated parameters (*A*, *B* and AxB; Table 4). Cobalt content was highest in the samples from Cement Factory Garden tree needles (0.44 ppm) and lowest from Sugar Factory Garden trees in 2003 (0.17 ppm), but the highest value in 2004 was in the samples from Meram Area needles (0.39 ppm).

Results of variance analysis for Cr levels in the needles showed that there were significant differences ($p<0.01$) between *A*, *B* and AxB interaction (Table 4). Chromium contents of samples collected from the trees of Chrome–Magnesite Factory Garden was at a maximum and at very high levels in comparison with other places, 30.71 and 48.79 ppm in the 2003 and 2004 samplings, respectively (Fig. 2). Others were lower and generally similar to each other. Duncan's Test for chromium contents in the samples collected in 2 yr showed that Cr levels were significantly higher ($p<0.01$) than the other places but not the others themselves, except the sample of Chrome–Magnesite Factory Garden. Furthermore, accumulation of Cr in the needles of old trees was higher than in young trees in the 2003 and 2004 sampling periods (Tables 2 and 3).

Statistical analysis with V contents of the needle samples showed that there were significant differences ($p<0.01$) between *A*, *B* and AxB interaction for two sampling periods, except tree ages in the 2004 sampling year (Table 4). Vanadium contents were the highest (20.45 ppm) in the Meram Area in the 2003 sampling, but in 2004, maximum V value was detected at Cement Factory Garden with 53.63 ppm. Mean vanadium content for all sampling places was 24.01 ppm in 2004 year and 14.65 ppm in 2003 (Tables 2 and 3).

Results of variance analysis showed that there was no significant difference ($p>0.05$) between the Cd contents of any investigated parameters (Table 4).The mean content of Cd for the 2003 samples was relatively higher than the 2004 year samples. Similarly, a Cd content of young tree needles was slightly higher than older tree needles (Tables 2 and 3).

4. Discussion

High contents of heavy metals in the plant tissue show pollution levels of air and soil by this heavy metal. Sulphur dioxide pollution in the atmospheric level of Konya city during the winter period rose to dangerous effect levels for natural vegetation (Söyleyici and Dursun, 2003). Studies of Dursun et al. (1996b) showed that concentrations of SO_2 over 40 nl L^{-1} has a toxic effect on the respiration of decomposing tree letters; for this reason, trees in Konya city are under risk at the measured concentrations. Effect of SO_2 on plants was higher with high content of PM; accordingly, SO_2 and PM concentrations were high in the atmosphere in the winter period. When PM occupied the stoma of the leaves, SO_2 can precipitate in the inner tissue of the leaf.

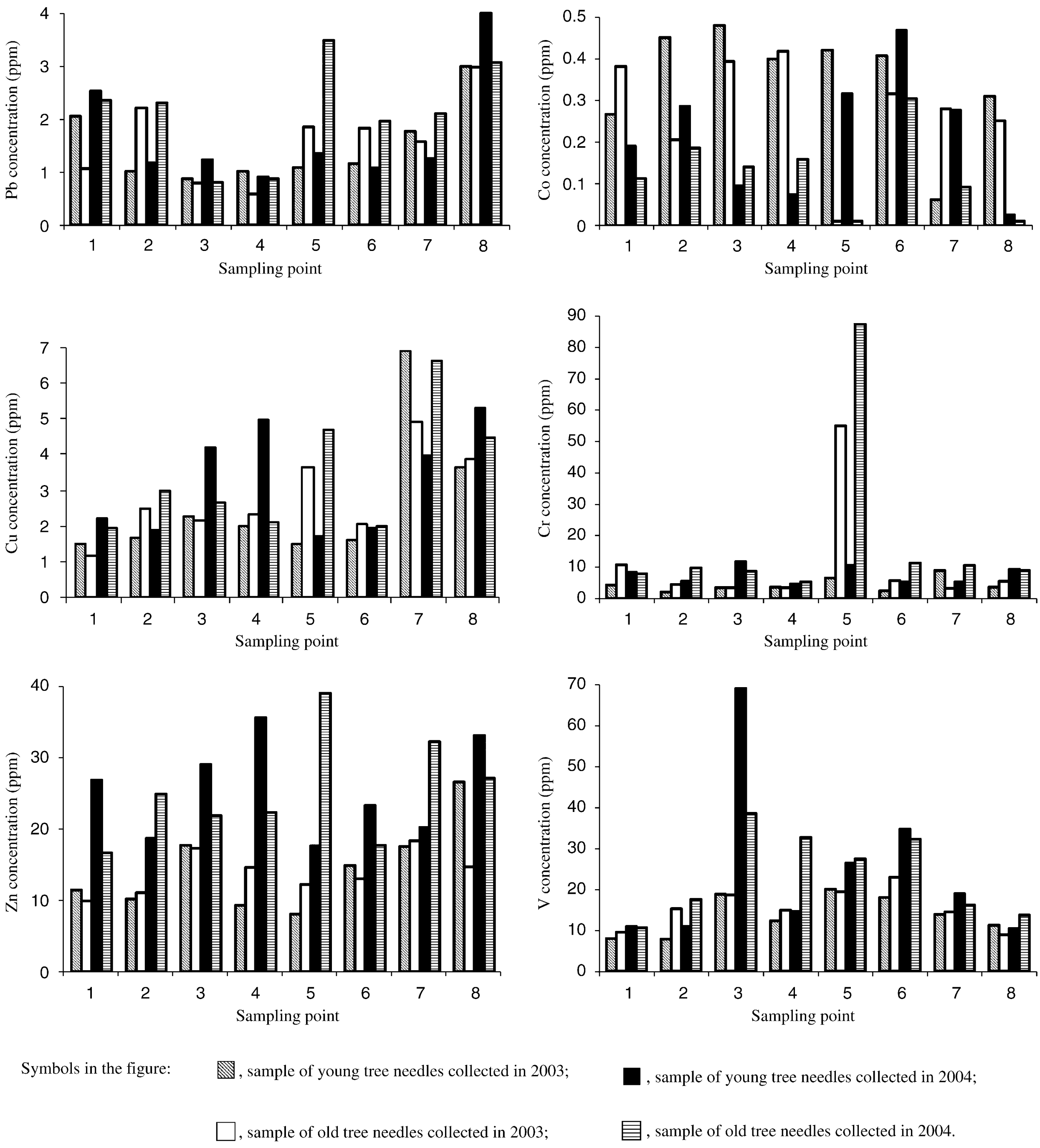

Fig. 2. Pb, Co, Cu, Cr, Zn and V contents (ppm) in the needles of cedar tree collected from eight sampling point in Konya city centre in December 2003 and April 2004. Sampling points are: (1) Alaeddin Hill Park, (2) Anıt Place, (3) Cement Factory Garden, (4) Selcuk University Campus, (5) Chrome–Magnesite Factory Garden, (6) Meram Area, (7) Sugar Factory Garden, (8) Karatay Industry Park.

Lead was taken up only in small amounts by plant roots at the tested areas because of the prevailing nature of the soil. The chemical form of lead as it impacts plants is of critical importance, however, as this is a factor in movements into plant, in translocation and in the toxic effectiveness of lead within the plant. Lead pollution on a local scale is caused by emissions from motor vehicles using leaded gasoline (Yılmaz and Zengin, 2003; Viard et al., 2004). Normal content of Pb 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. Measurement of contents in the tree needle samples was higher than 3 ppm at only Karatay Industrial Park in Konya city (in 2004), and other measurements were at levels lower than 3 ppm. The close relationship between lead concentrations and traffic intensity has been demonstrated in detail by many authors (Gromov and Emelina, 1994; Li et al., 2001; Viard et al., 2004). In this research, there was a linear correlation between high Pb level and heavy traffic at Karatay Industrial Park, Alaeddin Hill Park and Anıt area, on the contrary, with other sampling places. Alaeddin Hill Park has the highest traffic flow with an average of 4000 vehicle hr^{-1} according to the records of Konya Municipality, and the lowest levels were around the University Kampüs (mean < 250 vehicle hr^{-1}). Karatay Industry Park and Anıt area also have heavy traffic density (2500–3000 vehicle hr^{-1}). The density of pollution is very high in Karatay Industrial Park, because vehicles in this area have high pollution effect in the atmosphere, since they were coming for repair. The degree of heavy metal content in the cedar tree needles is proportional with urbanisation. The main reason for high contents of heavy metals in plants localised in industrial areas and in urban roadsides are the industrial activity and density of traffic. Load exhaust from cars is considered as one of the major sources of contamination of Pb in Turkey. Because unleaded petrol is expensive, drivers are forced to use the leaded one. Additionally, some old versions of cars consume only leaded petrol (Çelik et al., 2005). Our values were between 0.577 and 3.994 ppm in cedar tree needles. The highest contents of lead in cedar tree needles were taken from Karatay Industry Park and urban roadsides.

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. An excessive supply of Cu causes symptoms of chlorosis that are similar to the symptoms of iron deficiency (Bergman, 1983). Kabata-Pendias and Piotrowska (1984) reported the normal content of Cu in plants ranges to be 2–20 ppm, but in most plants, the normal Cu contents are in a narrower range of 4–12 ppm. Our results indicated that Cu content was in the risk level for the plants at Sugar Factory Garden in the 2003 and 2004 samplings. Contents of Cu were lower than 3 ppm for the sampling of residential areas.

Zinc contents were not significantly different for the two sampling types and the two sampling periods. Mean content of zinc for the 2004 year sampling was higher than the 2003 year sampling (Tables 2 and 3). Zinc 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). 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). Zinc is not at harmful levels as a major threat to the environment in our study.

Cobalt content of the plant was related with the useful cobalt compound in the soil, plant species and plant tissue (Güneş et al., 2004). Toxic limit of Co for leaves is about 0.5 ppm (Pendias and Pendias, 1992). Colourless edges of the leaves occur with increasing Co content (Yağdı et al., 2000). In our investigation, over-the-limit levels were not found in any sampling for Co, but mean content of Co for the spring period sampling was significantly lower than that of autumn. Güneş et al., (2004) discussed that Co was washed out during the winter period between autumn and spring seasons.

Cr is found at levels considered as potentially hazardous. Chromium content coming from production of varnish, paint and ink, usage for metal covering, leather and glass industry may increase Cr to critical levels for plants (Yağdı et al., 2000; Dursun, et al., 2002b; Çiçek and Koparal, 2004). Cr is a toxic, non-essential element for plants (Shanker et al., 2005). Effects of Cr on plants are symptoms of chlorosis on leaves and decrease of root growth (Yağdı et al., 2000). Chromium measurement for the sampling from Chrome–Magnesite Factory Garden in the two sampling periods was at a very high content (30.71 ppm in 2003 and 48.79 ppm in 2004) and was significantly different from the other samples. There is a Cr risk for the vegetation around the Chrome–Magnesite Factory.

There are not enough concrete findings for the importance of V for most of the plants. However,

Table 5
Heavy metal average content (ppm) in plant tissues and heavy metal levels in pollution areas in Turkey

Normal contents							References
Pb	Cu	Zn	Cd	Co	Cr	V	
1.0	10.0	50.0	0.05	0.2	1.5	6.0	Markert, 1994; Bergman, 1983
Some findings at similar investigations from different parts of Turkey except Shanker et al., 2005							
0.6–12.8	1.2–10.7	2.3–18.0	0.05–0.37	—	—	—	Çınar and Elik, 2002
0.1–55.0	2.1–59.0	1.7–222.4	0.1–7.23	—	—	—	Çiçek and Koparal, 2004
14.0–41.0	1.52–24.96	55.82–115.01	—	—	—	—	Yılmaz and Zengin, 2003
2.65–28.0	3.0–6.0	8.0–21.0	0.02–0.72	—	—	—	Aksoy and Öztürk, 1997
11.5–53.0	5.28–10.15	11.53–53.05	0.37–3.70	—	—	—	Çelik et al., 2005
15.84–39.22	—	—	—	—	—	—	Öncel et al., 2004
—	—	—	—	0.18–0.24	—	0.75–10.0	Güneş et al., 2004
—	—	—	—	—	0.06–18.00	—	Shanker et al., 2005
0.578–3.994	1.137–6.888	8.052–38.989	0.017–0.218	0.010–0.481	2.064–87.15	7.957–68.87	This study (min.–max. content)

—: Not available.

there is small information about the improvement effects of vanadium on a few species of plants (Basiouny, 1984). The toxic level of vanadium is about 10 ppm in the growing environment as a caution for the plant. Investigations showed that the usage of synthetic fertiliser with phosphorus increased vanadium content in soil. Mean vanadium content of most of the plants is between 1.32–10.01 ppm (Bergman, 1992; Güneş et al., 2004). Results of this investigation show that vanadium contents were very close to or over the toxic level in all plant samples. The reason of V increase in the spring period sampling was the increase of chemical fertiliser usage before this period. This finding supports the results of the investigation given above.

Mean source of environmental Cd pollution is the ferrous-steel industry. In addition, vehicle wheels, mineral oils and usage of waste mud may introduce Cd into the soil, and this increases Cd level to the plants (Güneş et al., 2004). A small amount of Cd also comes from synthetic fertilisers. Cadmium content found in this investigation were lower than toxic levels (<0, 05 ppm) given in the literature (Scheffer and Schachtschabel, 1989; Del Rio et al., 2002). There is not a risk for Cd to organisms in the investigation area.

Normally, higher levels of heavy metals are observed in old tree needles rather than in young; similar results were obtained in this investigation. On the other hand, some different results were also found in our work too. However, the values of some heavy metal contents were much higher in young tree needles than in those of old tree needles. This situation may be explained by the properties of soil rhizospher level, whose antagonistic effect is elemental to uptake, according to the quantities of heavy metals and other nutrient elements of the plants in the soil, plant health and the particular matters in the ambient air (Reimann et al., 2001; Güneş et al., 2004; Shanker et al., 2005). There are similar findings in the literature given above that fit the results obtained from this present study, summarised in Table 5.

5. Conclusion

The results of this study show that some heavy metals such as Pb, Cr, Co, Cu, V and Cd are present at levels considered potentially toxic. Chromium is at a toxic level in the leaves of cedar tree needle samples of Chrome–Magnasite Factory Garden in Konya city (Turkey). Three metals, Cr, V and Zn were over 20 ppm, and increased by about 90 ppm in some sampling points. Trees around Chrome–Magnasite Factory were found to have the highest heavy–metal content of the eight sampling points investigated. These results might be explained by the fact that emissions of Chrome–Magnasite Factory have spread some heavy metals and accumulated directly in plant leaves, and indirectly from the soil polluted by the air pollution. The emission from the

Chrome–Magnasite Factory may be the most important source for metal deposition in the investigation area. Some elements such as Cr and V are present in the needles of trees at levels that exceed those considered as toxic. These results may be explained by a high amount of trace elements deposited in the plant tissue from the heavy air pollution, but most trace metals were immobilised mostly in vegetative tissue, and the concentration strength is lower in generative tissue.

In the present study, the effect of air pollution of the heavy traffic emissions, the usage of low quality fuels and the industry wastes on heavy metal contents of cedar tree needles in Konya city centre were studied. The results showed that heavy metal contents were highly different in sampling points and periods. In such a way, the Pb content was the highest in Karatay Industry Park for the two sampling years. The samples collected from heavy traffic areas, Alaeddin Hill Park and Anıt area, have higher levels of lead contents. The usage of low-quality fuels and industrial wastes have high effects on the environment and green area of the city centre.

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