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LEAD (Pb) CONCENTRATIONS IN URBAN SOIL AND SOME TREE SPECIES OF ISTANBUL

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ABSTRACT

Exhaust gases that comes from the burning of the leaded fuel in these vehicles cause air pollution. And lead (Pb), which is found in the exhaust gases, pollutes soil and affects plants negatively. In this investigation, Pb concentrations of 7 different deciduous tree leaves, which were collected in spring and autumn periods from 9 sampling area (+1 control), were determined. Leaf samples were taken from *Acer negundo, Aesculus hippocastaneum, Ailanthus altissima, Fraxinus angustifolia, Platanus spp, Populus nigra* and *Robinia pseudoacacia* species that are found in the urban parks and close to the roadsides. Pb concentrations in the leaves were detected as 2.0-23.76 mg kg^{-1} in spring and 3.99-34.40 mg kg^{-1} in autumn. Pb concentrations of the urban leaves were higher than the control leaves both in the investigated seasons. We have also studied Pb concentrations of soils from the same sampling areas. Pb concentrations were found as 26.63-445.60 mg kg^{-1} in spring, 23.23-1121.20 mg kg^{-1} in autumn, respectively. Pb content of the urban soils was also quite higher than the control soils. These results have shown that Pb pollution in Istanbul exceeds the limits of toxicity especially in the areas with high traffic density.

Key Words: Lead, tree, air pollution, urban soil,

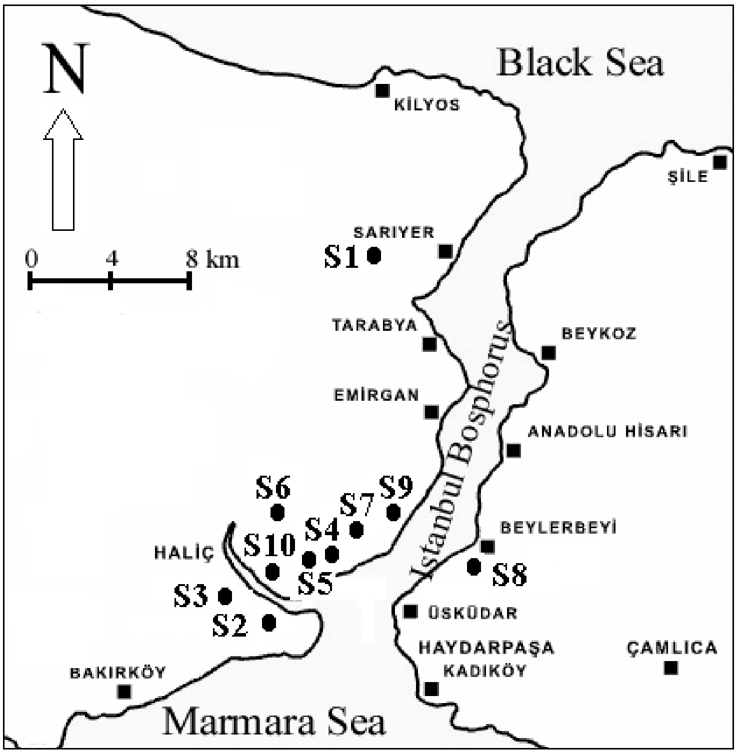
1. INTRODUCTION

Lead (Pb) is not a vital element for the living organisms but it is naturally found in the soil depending on the parent material. The most significant sources causing Pb concentrations in nature to increase may be enumerated as being fossil fuels, traffic, mining, fertilizers used in agriculture and forestry, pesticides, wood protection chemicals, sludges, household and industrial waste, metalwork industries (Alloway, 1999; Davies, 1999). In most large cities air pollution measurement stations have been set up to measure the levels of pollutants such as SO_2, NO_x and dust in the air. During the winter months heating is achieved through the burning of fossil fuels, which when combined with traffic emissions causes intensive air pollution including heavy metals. And it is for this reason that in recent years a lot of attention and research has been directed towards heavy metal content in the urban soils and in urban plants. In this study, the primary objective has been to investigate the total Pb content in various soils and tree leaves the from urban parks and roadsides of Istanbul.

2. MATERIALS AND METHODS

2.1. Soil and Plant Sampling

Istanbul lies between with a population exceeding 10 million, is one of the Turkey's most populous city and important industrial center. Sampling was carried out in May and September 1999 from nine presumably polluted urban sites and one from a relatively clean area (Istanbul University Education and Research Forest, Bahçeköy) (Figure 1).



Sample Site No.	Sample Sites
S1	Istanbul University- Faculty of Forestry/ Research Forest-Bahçeköy (Control)
S2	Saraçhane Urban Park-Saraçhane
S3	Old City Walls Vicinity-Edirnekapı
S4	Taksim Urban Park-Taksim
S5	Democracy Urban Park-Maçka
S6	Çağlayan Urban Park-Çağlayan
S7	Yahya Kemal Urban Park / Barbaros Boulevard-Beşiktaş
S8	Bosphorus Bridge / Asian Side Exit (E-5 Highway)-Beylerbeyi Intersection
S9	Bosphorus Bridge / European Side Exit (E-5 Highway) vicinity
S10	Cezayirli Hasan Paşa Urban Park-Kasımpaşa

Figure 1. Map of Istanbul with location sample sites

Tree leaves (118 samples) and soil samples (104 samples, 0-5cm and 20-25 cm depth) were collected from the roadsides and from the urban-parks exposed to the exhausts of heavy traffic. Analyzed tree species: *Acer negundo* L. (Box-Elder), *Aesculus hippocastaneum* L. (Common Horse Chestnut), *Ailanthus altissima* (Miller) Swingle (Tree of Heaven), *Fraxinus angustifolia* (Vahl.) (Narrow-leaved Ash), *Platanus sp.* [*Platanus orientalis* L. (Oriental Plane) and *Platanus X acerifolia* (Ait.) Willd. (London Plane), *Populus nigra* L. (Black Poplar), *Robinia pseudoacacia* L. (Locust tree).

2.2. Soil and Plant Analysis

Heavy metal determinations: Both plant and soil samples were dried and wet-digested with HNO_3 (Sastre et al. 2002). The obtained suspensions were filtered, diluted and final solutions were analyzed for Pb using flame AAS (Shimadzu AA-680). The results were calculated on dry weight basis (mg kg^{-1} dw).

Soil analysis: Soil samples were sieved, dried and the particle diameter distribution was designated using the Bouyoucous hydrometer method. The pH values, electrical conductivity, $CaCO_3$ organic carbon (Walkley-Black method) and total nitrogen (Kjeldahl method) were also determined (Gülçur, 1974).

3. RESULTS AND DISCUSSION

3.1. Selected Soil Properties

The soil samples taken from the control site (S1) are considered to be natural. On the other hand, those taken from the urban parks and roadsides of the city are such that they have been brought from elsewhere by various methods and they are usually spread soil or material. Thus, one may easily encounter construction waste, etc. and other unnatural substances in these urban soils. Although it may not be stated during the course of the study, various fertilizers in the form of organic substances have possibly been mixed in the parks. The soil textures are mostly loamy clay and sandy-loamy clay. In urban soil, actual acidity ranges between 6.88-8.56 pH in spring and 5.70-8.43 in autumn (Table 1). The least reactions among the sample site were to be observed for the control site at the Faculty of Forestry-Research Forest (S1) and there was no lime content in that soil.

In general, the average electrical conductivity in the soil samples was found to be below 500 μS cm^{-1} (Table 1). As mentioned above, there was no lime in the control site; on the contrary, there was lime in all the other soils obtained from within the city. In general, the level of organic carbon at the top soil is between 0.50-7.73% whereas in the lower soil it is between 0.09-2.86% (Table 1). At all the sample sites the total nitrogen content of the top soil taken in both seasons is higher in comparison to the lower soil, generally varying between 0.084-0.671%. Nitrogen values for the lower soil varies between 0.045-0.227% (Table 1).

Table 1. Range of the selected properties of the control and urban soil samples

Soil Properties		Control (S1)		Urban Soil (S2-S10)	
		0-5 cm	20-25 cm	0-5 cm	20-25 cm
Sand (%)		60-73	40-57	38-87	37-84
Silt (%)		10-20	18-24	7-24	7-25
Clay (%)		17-20	24-37	6-38	9-41
pH (H_2O)	Spring	5.64-6.99	5.49-7.07	6.88-7.87	5.70-8.35
	Autumn	6.31-7.19	6.25-7.23	7.22-8.56	5.98-8.43
EC (µS/cm)	Spring	249-451	52-113	289-688	52-629
	Autumn	311-662	55-148	198-1139	55-438
$CaCO_3$ %	Spring	0	0	0.82-25.82	0-33.19
	Autumn	0	0	0.89-25.51	0-36.06
Corg %	Spring	4.91-7.73	1.62-1.86	0.66-7.73	0.09-2.67
	Autumn	4.83-7.57	0.50-1.30	0.50-7.73	0.10-2.86
N %	Spring	0.327-0.540	0.111-0.181	0.084-0.492	0.057-0.208
	Autumn	0.354-0.549	0.098-0.132	0.091-0.671	0.045-0.227

3.2. Pb Concentrations in Soils

During spring, the Pb concentrations in the urban soils varied between 26.63-445.6 mg kg^{-1} (Table 2). On the other hand, in a significant number of the sites there was an increase in Pb quantity in autumn and was found to range between 23.23-1121.20 mg kg^{-1} (Table 2). The Pb concentrations in the soils obtained from within the city in spring were all higher in comparison to the control site. On the other hand, in autumn the Pb content at the depth of 0-5 cm for sample sites S3 and S5, and at the depth of 20-25 cm for sample site S7 were determined as being lower than that at the control site. The highest concentrations of Pb for both seasons were found at sample site S9 (European side exit of the Bosphorus Bridge), followed by sample site S2 (Saraçhane).

Values between 0.1-20 mg kg^{-1} are accepted as being the most common values in soils (Alloway, 1999). Soils having a Pb content of above 100 mg kg^{-1} are accepted as being polluted, while 200 mg kg^{-1} and higher is considered as very polluted (Smidt, 2000). According to this information the Pb content at the exit from the European side of the Bosphorus Bridge (S9) is categorized as 'very polluted' and is 5-6 times higher than the threshold value for this category of 200 mg kg^{-1}. Similarly, the soil from the Saraçhane Park (S2) may also be categorized as 'very polluted' in terms of Pb content. This must be owing to the intense traffic in that locality, because the most significant reason for increase in Pb content is the exhaust gases of the motor vehicles. If one considers that the number of vehicles in Istanbul is exceeding 1 million and a significant amount of leaded petrol is consumed, it is quite understandable why the levels of Pb in the soils samples from the city are so high in comparison to the control site. High pH, high lime content and organic fertilizers increase the adsorption of Pb to the soil and these properties have direct effects on the Pb adsorption.

Table 2. Total lead concentrations in the soil samples (mg kg^{-1})

Sample Sites	Depth	Pb	
		Spring	Autumn
S1 Control	0-5	24.87±4.20	38.53±12.72
	20-25	26.03±4.15	40.27±21.99
S2 Saraçhane	0-5	247.23±118.43	746.49±72.56
	20-25	290.45±37.55	464.85±176.56
S3 Edirnekapı	0-5	26.63±5.93	32.87±17.17
	20-25	73.85±17.8	82.75±6.86
S4 Taksim	0-5	79.80±28.54	91.80±46.82
	20-25	88.93±33.25	129.68±121.76
S5 Maçka	0-5	29.53±6.36	23.23±2.74
	20-25	53.97±28.12	86.69±27.63
S6 Çağlayan	0-5	114.63±12.00	102.37±28.30
	20-25	62.70±14.90	62.32±57.45
S7 Barbaros	0-5	44.13±20.44	108.39±99.69
	20-25	52.67±33.75	110.23±103.50
S8 Beylerbeyi	0-5	112.40±16.83	86.50±9.76
	20-25	35.00±18.24	27.00±12.02
S9 Bosphorus Bridge	0-5	437.90	1121.20
	20-25	445.60	126.65
S10 Kasımpaşa	0-5	99.80±62.79	77.31±63.92
	20-25	123.40±134.04	63.70±49.71
Average of urban soil (S2-S10)	0-5	107.83	201.73
	20-25	108.60	119.71

When making a comparison with certain other cities, the Pb concentration in spring is higher than that in cities like Stockholm, Hong Kong and Antalya. And as the concentrations increase in autumn the amount of Pb is quite higher than many other cities (Table 2) which indicates that the amount of Pb in Istanbul soils is at high levels. Similarly, in a study conducted by Bayçu et al. (1997) the Pb levels at the control site which is found in close proximity to our control site, were determined as being between 14.95-23.23 mg kg^{-1}. In the same study the following amounts of Pb were found; 182.63 mg kg^{-1} at site S2, 58.43 mg kg^{-1} at site S4, 143.92 mg kg^{-1} at site S5 and 282.25 mg kg^{-1} at sample site S7. In another study (Sezgin et al., 2004) conducted in Istanbul, the Pb content of street dust in the surroundings of the E-5 motorway was found to be between 105.5-555.4 mg kg^{-1} (on average 211.88 mg kg^{-1}). In that study it was stated that the high levels of Pb found at the roadsides was attributed to the motor vehicle traffic and the usage of leaded fuel. Again, in another study, soil samples were taken at varying distances to the E-5 highway at depths of 0-5 cm and the Pb content was found ranging between 73.50-445.00 mg kg^{-1} (on average 186.39 mg kg^{-1}) (Bayçu and Önal, 1993).

Tablo 3. Comparison of the average lead concentrations in some of the urban soils in the world (mg kg^{-1})

<table>
<tr><td colspan="2">City</td><td>Depth (cm)</td><td>n</td><td>Pb</td><td>Reference</td></tr>
<tr><td colspan="2">Coruna (Spain)</td><td>0-5</td><td>15</td><td>309</td><td>Cal-Prieto et al. (2001)</td></tr>
<tr><td colspan="2">Madrid (Spain)</td><td>0-20</td><td>55</td><td>161</td><td>De Miguel et al. (1998)</td></tr>
<tr><td colspan="2" rowspan="2">Seville (Spain)</td><td>0-10</td><td>31</td><td>137</td><td rowspan="2">Madrid et al. (2002)</td></tr>
<tr><td>10-20</td><td>31</td><td>163</td></tr>
<tr><td colspan="2">Naples (Italy)</td><td>0-2</td><td>173</td><td>262</td><td>Imperato et al. (2003)</td></tr>
<tr><td colspan="2">Palermo (Italy)*</td><td>0-10</td><td>70</td><td>202</td><td>Manta et al. (2002)</td></tr>
<tr><td colspan="2">Stockholm (Sweden)</td><td>0-5</td><td>42</td><td>101</td><td>Linde et al. (2000)</td></tr>
<tr><td colspan="2">Bangkok (Thailand)</td><td>0-5</td><td>30</td><td>47.8</td><td>Wilcke at al. (1998)</td></tr>
<tr><td colspan="2">Hong Kong</td><td>0-10</td><td>594</td><td>93.4</td><td>Li et al. (2001)</td></tr>
<tr><td colspan="2">Hong Kong</td><td>0-5</td><td>10</td><td>89.9</td><td>Chen et al. (1997)</td></tr>
<tr><td colspan="2">Hong Kong</td><td>0-100</td><td>100</td><td>112.98</td><td>Jim (1998)</td></tr>
<tr><td colspan="2">Hong Kong</td><td>0-15</td><td>152</td><td>94.6</td><td>Li et al. (2004)</td></tr>
<tr><td colspan="2">Nanjing (China)</td><td>Horizon</td><td>138</td><td>107.3</td><td>Lu et al. (2003)</td></tr>
<tr><td colspan="2">Antalya (Turkey)</td><td>0-5</td><td>73</td><td>36.5</td><td>Güvenç et al. (2003)</td></tr>
<tr><td rowspan="4">Istanbul
(This study)</td><td rowspan="2">Spring</td><td>0-5</td><td>24</td><td>107.83</td><td rowspan="4"></td></tr>
<tr><td>20-25</td><td>22</td><td>108.60</td></tr>
<tr><td rowspan="2">Autumn</td><td>0-5</td><td>24</td><td>201.73</td></tr>
<tr><td>20-25</td><td>22</td><td>119.71</td></tr>
<tr><td colspan="2">Background values</td><td></td><td></td><td><20</td><td>Alloway (1999)</td></tr>
<tr><td colspan="2">Tolerable values</td><td></td><td></td><td>20-100</td><td>Alloway (1999)</td></tr>
<tr><td colspan="2">Polluted soil values</td><td></td><td></td><td>>100</td><td>Alloway (1999)</td></tr>
</table>

* Median

According to the results it has become apparent that the soils of Istanbul are becoming polluted with Pb. Furthermore, there is also a variation in the concentrations of Pb in terms of season. Pb concentrations rose in the season of autumn. The reason for the rise in Pb concentrations is attributed to the slowing in decomposition of organic matter thereby increasing the amount of organic matter and a rise in the pH levels. This is because with the increase in organic matter and pH the buffered Pb increase in amount. In autumn the annual increase in distribution of rainfall also affects the rise in concentrations of Pb.

3.3. Pb Concentrations in Leaves

The lowest Pb concentrations were found in the control tree species both for spring and autumn period. Concentrations of Pb in the spring samples collected from control site were ranged from 0.0 mg kg^{-1} (*Robinia*) to 4.13 mg kg^{-1} (*Fraxinus*) and the range was found from 0.0 mg kg^{-1} (*Platanus*) to 3.59 mg kg^{-1} (*Acer*) in the autumn samples (Table 4). Pb range in the urban site leaves were detected as 2.00 (*Platanus*, S4)-23.76 mg kg^{-1} (*Aesculus*, S10) in spring; and 3.99 (*Ailanthus*, S4)-34.40 (*Robinia,* S4) mg kg^{-1} in autumn (Table 4). We obtained a general increase in the Pb concentrations of the urban site samples compare to control samples and also an increase was observed in the autumn samples of urban sites compare to spring (Table 4). There are considerable data on the retention and bioaccumulation of heavy metals by tree leaves and their phytotoxicity. Generally, toxic concentrations of Pb are defined as 30-300 mg kg^{-1}dw (Kloke et.al., 1984).

Table 4. Pb concentrations in the tree leaf samples from different sampling sites of Istanbul.

Tree Species	Season	S1 Control	S2 Saraçhane	S3 Edirnekapı	S4 Taksim	S5 Maçka	S6 Çağlayan	S7 Barbaros	S8 Beylerbeyi	S9 Bosphorus Bridge	S10 Kasımpaşa
Acer negundo	Spring	1.72	7.83	11.14	3.15	7.09	11.07	9.08			8.32
	Autumn	3.59	12.80	15.80	8.28	8.36	12.35	20.84			8.45
Aesculus hippocastaneum	Spring	1.49	11.99	9.29	3.34		5.05	10.76	16.88		23.76
	Autumn	0.00	15.00	22.83	7.91		12.47	10.22	22.07		28.91
Ailanthus altissima	Spring	3.90	6.11	5.26	5.61	3.59	7.38	2.53	5.36	12.59	
	Autumn	2.61	6.81	13.79	3.99	9.63	14.16	5.16	11.00	19.25	
Fraxinus angustifolia	Spring	4.13	13.79	8.30	11.81	5.43	9.01	5.53	7.79		10.62
	Autumn	1.65	12.51	21.65	10.94	7.52	6.98	6.80	10.52		12.73
Platanus sp.	Spring	0.44	6.21	5.23	2.00	7.31	16.49	8.83	14.18		3.38
	Autumn	0.00	12.08	6.53	8.43	15.51	14.91	15.84	16.81		12.48
Populus nigra	Spring	3.53	6.08	12.57		7.14	5.68	6.75			7.36
	Autumn	2.58	7.39	6.46		7.80	10.26	8.53			9.59
Robinia pseudoacacia	Spring	0.00	9.28	12.51	4.39	5.89	12.09	14.56	2.70		19.35
	Autumn	1.23	7.06	11.51	34.40	5.96	14.99	25.11	9.07		12.47

According to theresults, it can generally be stated that the areas within the vicinity of heavy urban traffic are affected by the exhaust emissions as they contain high loads of heavy metals, especially Pb. In most of the urban sites, there were elevated Pb concentrations probably indicating a pollution coming from the usage of the leaded oil. Meanwhile, the concentration of Pb in the examined trees was under the toxicity range as described by Fergusson (1990) except the autumn samples of *Robinia* at S4. Pb is believed to be the metal with the least bioavailability and the most highly accumulated metal in root tissues (Kabata-Pendias and Pendias, 1986). This can be the reason for the low accumulation of Pb (in mg kg^{-1}) (spring, 12.59- autumn, 19.25) in *Ailanthus* at S9, which has a very high soil Pb content (spring, 437.90- autumn, 1121.20) in 0-5 cm depth soil.

Bereket and Yücel (1990) have investigated the Pb pollution of *Populus nigra* leaves which comes from the traffic emissions in Eskisehir (Turkey) and found 9,06-26,83 mg kg^{-1} Pb. Bayçu ve Önal (1993) have studied the Pb concentrations of *Ailanthus* *altissima* leaves which were collected from the roadsides in İstanbul and determined 16-67 mg kg^{-1} Pb. We have also determined similar Pb concentrations. Furthermore, 5.12-109.17 mg kg^{-1} Pb concentrations were found in the 1-year old needles of the coniferous tree species which were collected from the roadsides of the Istanbul city center (Bayçu et al, 1997). These concentrations were found high compare to the control values (Table 5).

Table 5. Pb concentrations in the 1-year old needle samples from different sampling sites of Istanbul (Bayçu et al 1997)

Tree Species	Atatürk Arboretum (S1)*	Haşim İşcan (S2)*	Taksim (S4)*	Maçka (S5)*	Barbaros (S7)*	Dolmabahçe	Beyazıt
Pinus pinea	1.17	11.23	9.47	5.12			
Pinus pinea	2.62	13.55	7.10	7.10			
Pinus nigra	1.91	8.56			8.52		
Pinus nigra	2.82	9.16			10.80		
Picea abies	1.66				80.54	54.45	
Picea abies	2.63				109.17	60.83	
Cedrus libani	1.95						13.83
Cedrus libani	2.22						15.00
Cedrus deodora	2.10			14.86			
Cedrus deodora	2.65			16.15			

* The same sample sites with our investigation.

4. CONCLUSIONS

The results of our investigation were evaluated as follows:

- According to the traffic emissions, Pb concentrations have increased both in the soil and also in the tree leaves compare to the control.
- Pb concentrations of soils from two sampling sites were found higher than the toxic limits. Similarly, high Pb concentrations which exceed the toxic limits were determined in some of the plant samples.
- Because of the high lime amount, high pH, and organic matter content soil adsorbs more Pb.
- There is a seasonal difference between the Pb concentrations of soil and plant samples.
- We have found higher accumulations of Pb in *Robinia* and *Aesculus* species.

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