Bull. Environ. Contam. Toxicol. (1987) 38:203–208

Bulletin of Environmental Contamination and Toxicology

Environmental Contamination by Lead and Cadmium in Plants from Urban Area of Madrid, Spain

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Nowadays, due to the growing industrial activity and motor traffic, the civilized human environment is being contaminated by heavy metals. The input of lead into the environment has increased during the last two decades, especially with the development of lead-containing gasolines, the consumption of storage batteries and the production of manufactured lead components. The major sources of airborne cadmium emissions in the European Community are the steel industry, waste incineration, zinc production and some agricultural practices (Hutton 1983).

The monitoring of atmospheric pollution is of great importance. The use of biological materials as metal indicators has been reported to be a relatively cheap, simple and reliable method (Goodman and Roberts 1971). Many studies have been made on the influence of air pollution upon plants; however, studies on the relation between metals in airborne particulates and plants are few. Plants are important in the biogeochemical cycle of heavy metals: lead associated with leaves or other deciduous tissue is recycled relatively fast, while lead contained in woody parts of the plant is recycled over a much longer period of time (Smith 1972).

The aim of this paper is: a) to determine the lead and cadmium content of the plants investigated; b) to determine the variations in lead and cadmium in 15 places of the city of Madrid (Spain); c) to obtain correlations between lead, cadmium, motor traffic, and rain.

MATERIALS AND METHODS

One hundred and ninety five samples of rose-bay leaves (Nerium oleander) from 15 places of the city of Madrid (Spain) were collected monthly from February 1985 - January 1986.

On arrival in the laboratory, the leaves collected were washed thoroughly with water and finally washed with distilled water. There was no significant difference ($P = 0.95$) in the amount of lead found between samples subjected to the washing procedures and the unwashed samples. Samples were dried at 75° C for five days and ground using a stainless steel grinder. Each 0.8 g portion of the samples was placed in capsules and combusted in a muffle furnace at 450° C and the samples were left to reduce to ashes overnight. The ashes were cooled, dissolved in 1N HCl and filtrated. Distilled water was added to the filtrates. The total volume of the sample solution for the determination of lead and cadmium was 10 ml (Nakanishi et al. 1984). Residues of metals were determined by comparison with aqueous standards on a Perkin-Elmer Model 2280 atomic absorption spectrophotometer.

The limit of detection was 0.02 ppm for lead, and 0.001 ppm for cadmium. All the residues are expressed as ug/g (ppm) dry weight. Geometric means were used to express the residue levels. Duplicates were carried out for all the samples.

RESULTS AND DISCUSSION

The presence of two heavy metals has been investigated in the 195 samples of rose-bay leaves. In all the studied samples detectable levels of lead and cadmium were found. In all cases cadmium showed the lowest mean level, with a range from 0.34 to 1.68 ppm, followed by lead with a range from 8.1 to 178.3 ppm. The lead level (geometric mean) reported in this study (40.6 ppm) is lower than those assumed by Smith (1972) in leaves of Quercus palustris (140 ppm), Acer saccharum (101 ppm), Acer platanoides (156 ppm), Tsuga canadensis (111 ppm), Taxus sp. (159 ppm), and Picea abies (80 ppm), and Bacso et al. (1984) in leaves of Quercus robur (46 ppm), Platanus sp. (55.5 ppm), and Lolium perenne (48.5 ppm). The lead level (geometric mean) reported in this study (40.6 ppm) is higher than those obtained by Bacso et al. (1984) in Taraxacum officinale (23.3 ppm), Polygonum aviculare (25 ppm), and Trifolium sp. (14.1 ppm),

Table 1.- The effect of the seasons on the lead content of rose-bay leaves

Place of collection	Winter	Spring	Summer	Autumn
Cuzco Square	52.3	30.4	18.6	41.2
Nuevos Ministerios	81.0	78.2	28.9	56.9
Neptuno Square	79.5	40.2	26.0	41.7
Atocha Square	74.1	62.4	46.0	61.0
María Ana de Jesus Square	36.3	21.5	16.6	23.1
Ruiz Giménez Square	81.4	76.2	22.7	48.2
Cristo Rey Square	77.4	39.9	32.0	58.9
España Square	115.0	100.5	31.6	75.0
Casa de Campo Park	19.1	12.2	12.2	14.8
Alonso Martínez Square	49.0	30.5	30.7	50.6
Roma Square	60.9	34.1	20.1	35.4
Conde de Casal Square	94.8	52.0	30.3	61.0
Retiro Park	20.0	11.7	10.5	14.7
República del Ecuador Square	80.8	73.9	44.9	71.3
Serrano St./María de Molina St.	93.6	48.2	62.7	72.6

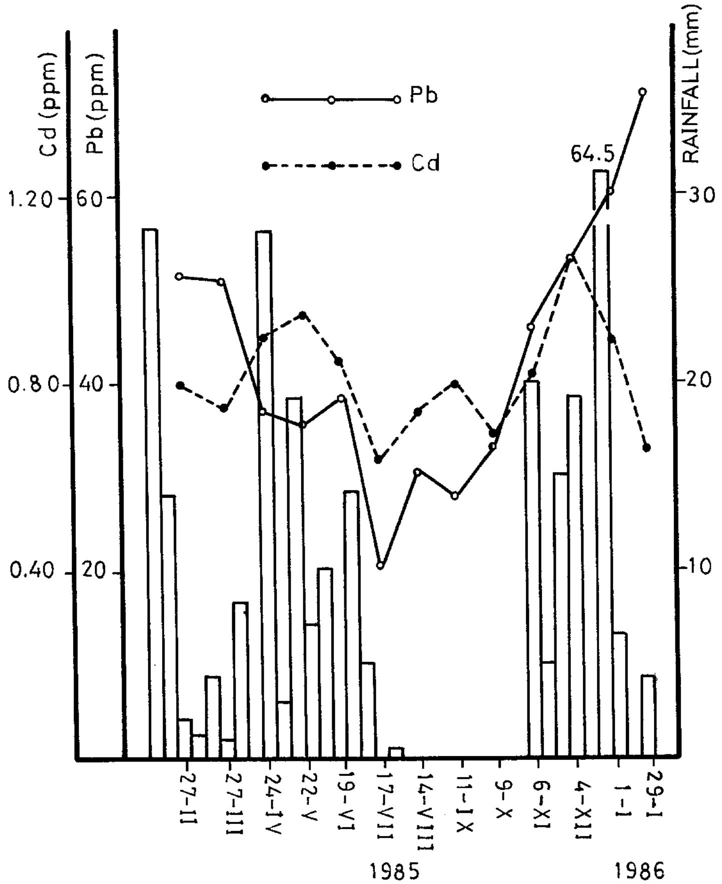

Figure 1.- Variation in lead and cadmium levels in rose-bay levels, together with the rainfall data during the sampling period.

and Hopkinson et al. (1972) in Phyllantus polygonoides (9.1 ppm), Sporobolus sp. (1.7 ppm), and Sida ficaulis (1.1 ppm). The value is generally comparable with those reported for herbaceous plants growing along heavily traveled primary roadways. The differences in values seem reasonable, taking into account that various species of plants were compared.

The effect of the occasional seasonal changes was observed by studyng the plants in winter, spring, summer, and autumn. The characteristic data of this study is summarized in Table 1 and presented in Figure 1. As can be observed, the lead concentration from plants varies with the season of the year. When a constant influx of lead was maintained during the period from February to July the lead concentrations decreased, because the plants were growing rapidly. From July until October there was a slight increase in the lead concentration, attributed to water loss, air dryness, and decreased growth. During the period from October

Table 2.- Correlation matrix for residues of lead, cadmium, traffic intensity and rainfall.

	Cadmium	Traffic	Rainfall
Lead	0.056	**0.412	0.173
Cadmium		0.085	0.078
Traffic			0.065

** P 0.01

to January there was less growth, yielding an increase in lead concentration. Concentrations of cadmium in rose-bay leaves were so low that no significant seasonal variation was apparent.

Correlation among residues of lead, cadmium, traffic intensity and rainfall were calculated and are presented in Table 2. The residues of cadmium are not correlated with the residues of lead, traffic intensity or rainfall. The correlation of heavy metals may be affected by emission sources, meteorological conditions as well as the age of the plants (Groet 1976). In this study all the plants, irrespective of their age, were considered, which may explain the anomaly.

The residues of lead are not correlated with rainfall since lead remained in the leaves and was resistant to being washed out rain (Figure 1). This data indicates that rainfall can be expected to be ineffective in removing it (Rains 1971) and confirms that there was no significant difference in the amount of lead found between samples subjected to the washing procedures and the unwashed samples. However, great care should be taken in comparing lead levels between samples, since Ho and Tai (1979) reported that rain could bring about great and rapid fluctuations in the level of lead in Alocaria odora and Mikania guaco.

Table 3.- Lead concentration in rose-bay leaves taken from along the roadside of different traffic intensities.

Place of collection	Pb(ppm)	Traffic intensities/day
Cuzco Square	33.03	79,000
Nuevos Ministerios	58.25	109,000
Neptuno Square	42.95	90.000
Atocha Square	60.23	104,000
María Ana de Jesus Square	23.23	57,000
Ruiz Giménez Square	52.67	111,000
Cristo Rey Square	48.35	123,000
España Square	74.25	128,000
Casa de Campo Park	14.17	1,000
Alonso Martínez Square	38.31	103,000
Roma Square	34.83	120,000
Conde de Casal Square	54.73	119,000
Retiro Park	13.63	1,000
República del Ecuador Square	66.73	130,000
Serrano St./M. de Molina St.	65.63	136,000

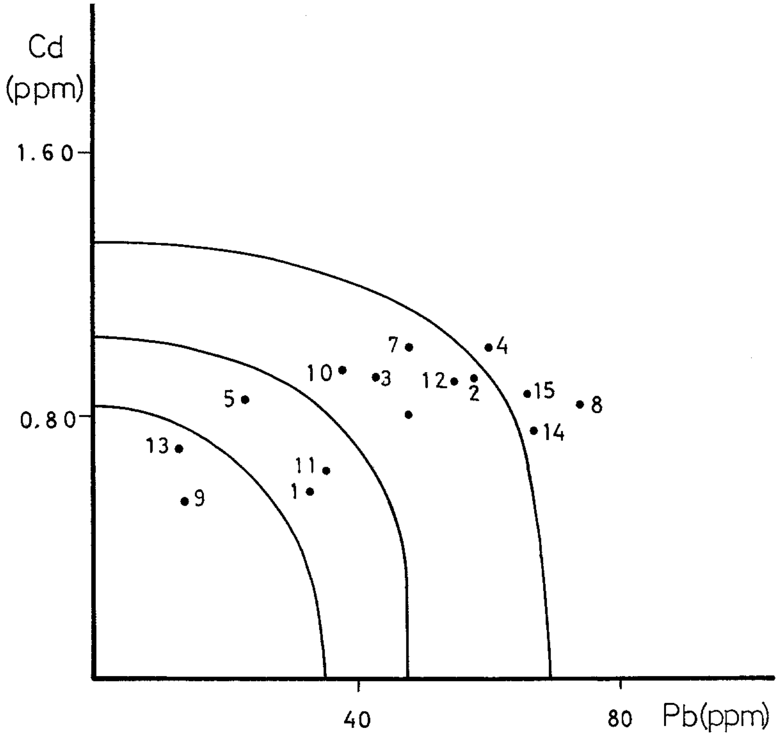

Figure 2.- Sampling points distribution according to lead and cadmium levels.

There is a highly significant positive correlation between the lead levels and the traffic intensity. The data of Table 3 shows that the lead concentration of rose-bay increases proportionally with motor-car traffic. Lead in urban atmospheres comes from the use of lead for many purposes, but it is assumed to be derived mainly from the combustion of lead alkyl additives in motor vehicle fuels. Areas with higher traffic densities had higher plant lead concentrations. Lee et al. (1983), Bacso et al. (1984), Smith (1972), and Goldsmith et al. (1976) have verified a positive correlation between the lead content and the traffic densities.

In Figure 2 each sampling point is defined by two coordinates: x_i = geometric mean of the residue levels of lead; y_i=geometric mean of the residue levels of cadmium. The module of vector classifies all the points as belonging to several classes and four main areas can be easily distinguished: contamination was very high at points: 2 (Nuevos Ministerios), 4 (Atocha Square), 8 (España Square), 12 (Conde de Casal Square), 14 (República del Ecuador Square), and 15 (Serrano Street/María de Molina Street); high at points: 3 (Neptuno Square), 6 (Ruiz Giménez Square), 7 (Cristo Rey Square), and 10 (Alonso Martínez Square); moderate at points: 1 (Cuzco Square), 5 (Beata María Ana de Jesus Square), and 11 (Roma Square); and low at points: 9 (Casa de Campo Park), and 13 (Retiro Park). Points 9 and 13 have been taken as a reference for the "natural pollution" from these metals in the urban area and are located in two forests far from roads of heavy traffic.

Acknowledgements. The authors wish to acknowledge the laboratory work of Mª. Carmen Tabera Galván.

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Received May 6, 1986; accepted September 4, 1986