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Heavy Metal Concentrations in Surface Soils from Mexico City

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The high urbanisation and industrial growth rate in Mexico City has made it one of the most densely populated regions of the Earth, with more than 20 million inhabitants in a total land area of 2000 km^2. This has resulted in an increase in the levels of environmental pollution from uncontrolled factory emissions, industrial and domestic wastewater, as well as exhaust from the more than 4 million automobiles that circulate in the city. Heavy metal pollution in particular has greatly increased and the urban environmental quality has been seriously affected. Similar situations, related to the anthropologic impact associated with rapid development in industrial and urban regions, have been reported in other parts of the world (Zhang et al., 1999; Thuy et al., 2000; Ansari et al., 2000; Kim et al., 1998; Wilcke et al., 1998).
Natural heavy metal concentrations in soils are due to erosion and weathering of parent rocks. Some trace elements, such as Cu and Zn, are necessary in low concentrations for all living organisms while most of them present toxicity hazards at high concentrations (Merian, 1991).

The environmental pollution of soils directly influences human health since they have excellent ecological transference potential. The degree of anthropogenic impact in the urban environment can be evaluated in terms of metal contamination of soils.
During the last few decades, studies have been carried out on urban soils related to industrial activities and automobile exhaust compared with rural and forest soils (Chen et al., 1997; Thuy et al., 2000). It has been reported that roadside soils near motorways are polluted by Pb from auto-traffic (Lee et al., 2000; Koeleman et al., 1999).

The environmental influence on heavy metals in urban regions of Mexico City has not yet been investigated. In the case of Mexico City, the nearby Popocatepetl volcano could represent an important natural source of trace element pollution in the environment. Popocatepetl (5432m) is located about 70 km to the south east of Mexico City and has been active since the latter part of 1993, systematically degassing and with sporadic events of ash emission. Volcanic emissions may influence the levels of such metals in the environment.

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At present there are no data available for metal emission from the Popocatepetl volcano, however, recent studies consider that the world-wide metal output by degassing of volcanoes has an annual injection mass of about 10,000 tons (Hinkley et al.,1999).

The complexity of the geochemical cycles in urban environments is such that is difficult to distinguish the source of pollution. This work presents a study of the degree of anthropogenic influence on the heavy metal distribution in soils in the metropolitan area of Mexico City and nearby forested areas as well as the possible influence of the Popocatepetl volcano emissions in heavy metal pollution. Urban samples exposed to different traffic conditions were taken from a metropolitan zone with almost no industrial influence for the purpose of evaluating vehicular. These samples have been analysed for Cd, Cu, Pb and Zn.

MATERIALS AND METHODS

A set of 24 urban surface soil samples exposed to different traffic conditions were collected in the southwest area of Mexico City. Geologically, this area is area is dominated by basaltic rocks from the eruption of the Xitle Volcano 1670 ± 35 years ago (Siebe, 2000). The major contributor to the pollution in this case is from motor vehicle emissions since the industrial area is concentrated in the northern part of the city. The samples were obtained in areas close to heavily travelled roads and from side streets with less traffic.

Six forest surface soil samples, apparently with no anthropogenic input, were taken. Background levels were calculated on two samples of each pre-anthropogenic soil in order to calculate the enrichment factors.
All samples of approximately 100 g were taken from the uppermost level. The soil material was dried at 110°C for 3 hours, dissagregated, and homogenized. For the metal determination, 0.2 g were digested with a mixture of concentrated acids (5ml HCl, 5 ml HNO_3 and 10 ml $HClO_4$). The solution was evaporated to dryness and the residue was subsequently dissolved and diluted to 100 ml with HNO_3 2%.

The determinations were carried out by ICP-MS at the Geophysics Institute, National Autonomous University of Mexico. The ICP mass spectrometer used was a VGElemental model PQ3. Detection limits are calculated as the concentration equivalent to three times the standard deviation of five replicates of the blank solution. For all elements it is better than 50 ppt. Calibration was performed with 1, 10, 100 and 200 ppb multi-elemental standard solution (SPEX- High Purity) and a blank solution of deionized water, all containing HNO_3 at 2%.

Matrix effects and instrumental drift can be eliminated by the use of In 115 (10 ppb) as internal standard.

The validity of the analytical procedure has been assessed with accuracy and precision tests. These were calculated by comparing a measured and a Standard Reference Material (SRM-2586) obtained from the National Institute of Standards & Technology. All elements have a precision better than 10 % RSD (relative standard deviation).

RESULTS AND DISCUSSION

The concentration of the heavy metals Zn, Pb, Cu and Cd in different soil categories in Mexico City and the surrounding forest soils are shown in Table 1. Urban soils are grouped according to different traffic conditions (low traffic, high traffic). The ratio for the 4 elements are shown in Fig 1.

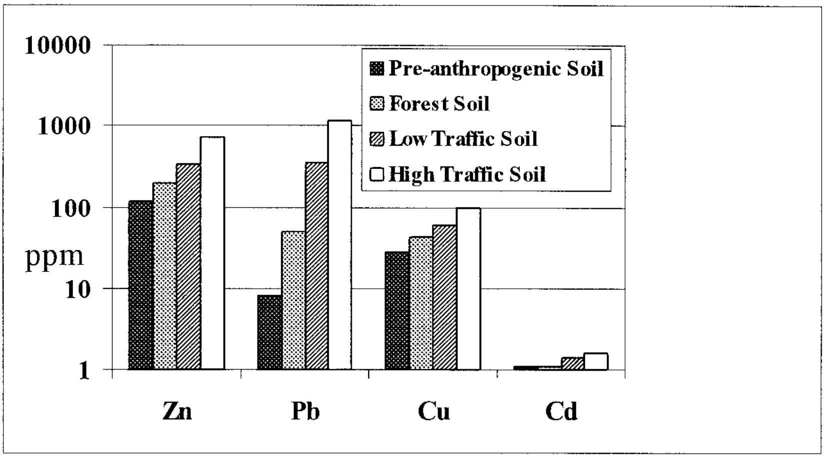

Figure 1. Comparison of trace metal concentrations in soils taken from different environments in Mexico City.

A comparison of the heavy metal contents with background levels shows that all urban soils are contaminated. In all samples, Pb shows the highest concentrations (ranging from 240 to 1570.2 ppm). The enrichment factors (E.F.) with respect to the levels in pre- anthropogenic soils are up to 193.8 times higher than the background levels. The Pb concentrations are related to the traffic conditions and the highest concentrations were found in soils exposed to heavy traffic conditions.

Zinc shows enrichment factors up to 6.41 times background levels in urban soils. As in the case of Pb, the highest concentrations were found in areas of heavy traffic.
The concentration of copper ranges from 40.2 to 120.4 ppm in urban soils (E.F. between 2.13 and 3.40), depending on the traffic conditions.

The low anthropogenic contribution of Cd to urban soils is independent of vehicular traffic, since the concentration of this element does not show significant changes under different traffic conditions (E.F.=1.4 for soils exposed to light traffic and 1.6 for heavy traffic).

In forest soils Pb has the highest E. F. (6.15). Cu, Cd and Zn, with lower E. F. than Pb in urban areas, show only little variation in forest soils. Pb is only seldom present in leachings from volcanic ash emitted by recent eruptions from

Table 1. Heavy metal concentrations in different soils categories in Mexico City.

Soil category	Zn (ppm)	Pb (ppm)	Cu (ppm)	Cd (ppm)
pre- anthropogenic	114.5	7.9	28.3	1.0
	116.7	8.3	29.5	1.0
Mean	**115.6**	**8.1**	**28.9**	**1.0**
Forest Soil	189.4	56.8	43.2	0.9
	204.3	39.4	40.3	1.1
	211.1	49.4	42.9	1.2
	193.7	47.2	45.9	1.0
	165.5	28.8	41.7	1.2
	210.7	76.4	47.2	1.1
Mean	**195.8**	**49.7**	**43.5**	**1.1**
Low Traffic	304.9	240	76.4	1.8
	278.1	291.2	64.3	1.6
	651.0	589.0	72.8	1.4
	599.0	530.0	74.3	1.4
	322.8	422.0	69.2	1.2
	325.1	377.8	58.2	1.2
	238.5	265.2	40.2	1.3
	269.7	329.7	49.5	1.3
	275.8	334.5	63.7	1.2
	263.3	281.3	63.2	1.4
	250.9	296.3	51.2	1.4
	247.4	291.7	57.4	1.4
Mean	**335.5**	**354.1**	**61.7**	**1.4**
High Traffic	666.5	921	101.5	1.7
	656.4	906.2	72.2	1.3
	687.0	1570.2	87.8	1.5
	572.0	1240.3	72.6	1.9
	776.6	1286.8	91.9	1.5
	972.9	1103.3	107.3	1.7
	711.6	1235.6	120.4	1.9
	782.9	1140.8	115.8	1.4
	813.8	1206.3	105.5	1.9
	777.5	1278.0	107.2	1.3
	972.9	1103.3	107.3	1.7
	711.6	1235.6	120.4	1.9
Mean	**741.7**	**1188.9**	**98.2**	**1.6**

Popocatepetl volcano (up to 17.6 ppm from the March 5, 1997 eruption) (Armienta et al.,1998). This leads us to conclude that the increase in Pb concentrations in forest soils is caused by the transport of these metals from urban areas, with little influence from Popocatepetl volcano.
The high Pb concentration in soils is attributed principally to decades of using gasoline containing Pb additives.
The concentration of the heavy metals Zn, Pb, Cu and Cd found in the analysed soils are higher than those reported in studies of metropolitan areas with similar conditions in other parts of the world (Wilcke et al., 1998; Kim et al., 1998, Chen et al., 1997).
This study clearly highlights the necessity of immediate control of the exceptionally severe metal pollution in urban areas in Mexico City. Heavy metal pollution has been occurring in the soils of the region and the situation will worsen if effective measures are not taken.

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