# Environmental Monitoring of Heavy Metal Contamination in Soil With Common Plants Used as Potentially Reliable Analytical Instruments

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## Abstract

The heavy metals distribution in common plants was investigated to assess their ability as natural bioindicators to urban pollution monitoring. Three herbaceous plants (*Plantago major L.*, *Taraxacum officinale L.* and *Urtica dioica L.*) and one leguminous (*Trifolium pratense L.*) were collected in Rome along one year and their Cu, Mn, Zn, Pb, Cr and Pd concentrations were analyzed and determined with ICP-AES after acidic digestion.

## Introduction

Heavy metals contamination is one of the major form of environmental pollution in urbanized cities due to emissions from heating, transport, industry and other human activities. The main contribution comes from lead (anti detonating agent in fuels), cadmium, zinc and nickel (from oils, pneumatics and old car pieces in general), but also from copper (cars and other electric vehicles); manganese prevalently originates from natural sources. When accumulated in high concentrations, heavy metals may severely damage plants by reducing their respiration and growth, interfering with their photosynthetic processes and inhibiting some enzymatic reactions. When the concentration of these toxic metals is moderate or low, plants continue to grow uniformly and accumulate them in roots and leaves. One interesting report of traffic air pollution in Rome has recently appeared,[1] but authors considered higher plants as monitoring species. Instead, we decided to use common plants since they are ephemeral: they live for a short time and are exposed only for a very specific period of time to bio-available pollutants. Secondarily, they are picked up straightforwardly with respect to other higher plants. Fore these reasons, three herbaceous plants (*Plantago major L.*, *Taraxacum officinale L.* and *Urtica dioica L.*) and one leguminous (*Trifolium pratense L.*) were collected in Rome during spring, summer and autumn analyzing heavy metals concentrations in different vegetal species as a function of time. Our results show that herbaceous plants can be used as alternatives to complex analysis instruments to assess soil pollution and ultimately, to evaluate environmental pollution.

## Materials & Methods

### Sampling Sites, soil and plant samples, preparation and analysis

In this study, five sampling areas (**SA**s) in Rome were considered: two heavy-traffic sites (Muro Torto and Olimpica) (**SA1** and **SA2** respectively), one medium-traffic (Ostiense) (**SA3**), one low-traffic (Eur) (**SA4**) and a large park (Pamphili) (**SA5**) considered as the reference site. Surface soil and plant samples (each weighing about 500 g) were taken in triplicate using a stainless steel trowel to a 20 cm depth from the surface, at the same distance from the street and across a 1x1 $m^2$ area. Soil samples belonging to the same site were pooled together, air-dried, then sieved by passing through a 1 mm nylon sieve. Fractions less than 1 mm size were ground further in an agate mortar, till all the sample was homogenized. Soil samples (particle size around 0.2 mm) were sealed in polyethylene bottles and stored. Roots belonging to each of the three plant replicas were pooled together, repeatedly washed with tap water, then with deionised water and air-dried. Finally, roots were oven dried (105 °C, 48 h) homogenized and grinded in a metal free mill to obtain a fine powder. A similar procedure was followed for the leaves. Dried soil, roots and leaves (350-400 mg

each) were separately digested with 10 ml of concentrated $HNO_3$ (65%) in 25 ml round bottomed flasks equipped with reflux condensers. Samples were kept at 130 °C for 24 h. Vessels were cooled, and samples were transferred in 25 ml volumetric flasks and made up to the mark with deionized water (0.05 $\mu Scm^{-1}$) to prepare the stocks. The solution was filtered through a Whatman 541 paper and stored in glass bottles. Working solutions were obtained diluting stock solutions to a factor of 10. For quality assurance of the analytical procedure, we carried out the analysis of blanks (clean mineralization solution) and standard reference materials (SRM) from the National Institute of Standards and Technology, Gaithersburg, USA (SRM No. 2587 and 2711) in the same experimental conditions and following the same protocol. Blanks and standards were run in triplicate and the average taken. The recovery varied from 95 to 98% and all the obtained values $\pm 3\sigma$ were enclosed within the range of certified values. Concentration of selected heavy metals (Cu, Mn, Zn, Pb, Cr and Pd) were determined by means of an ICP-AES spectrophotometer (VARIAN VISTA MPX CCD. Simultaneous ICP–OES) equipped with a U5000 $AT^{+}$ nebulizer (CETAC TECHNOLOGIES). At least one duplicate and one standard sample were run for every 10 samples to calibrate the instrument.

**Results**

Heavy metal concentrations found in surface soil and in the roots and leaves of various plants vary with the order soil>>roots>leaves and that this trend does not dependent on the sampling seasons. In sampled soils , we found extremely variable concentrations: Mn ranged between 449 and 820 ppm (14.92 mmol/Kg), Zn between 61 and 742 ppm (11.35 mmol/Kg), Pb between 58 and 1266 ppm (6.11 mmol/Kg), Cu between 26 and 214 ppm (3.37 mmol/Kg), Cr between 11 and 45 ppm (0.86 mmol/Kg) and Pd between 37 and 77 ppm (0.72 mmol/Kg). The latter two metals are low abundant heavy metals. **SA5**, being placed in the middle of a large city park, has a negligible anthropogenic heavy metals accumulation and present the lowest heavy metal concentration with respect to the other sampling sites. In **SA1** and **SA2**, Cu, Zn and Pb concentrations are higher than in **SA3-5.** Most likely, this should be ascribed to anthropogenic sources (vehicles and only in part to domestic heating systems, as in Rome the industrial activity is low) in agreement with other works reporting that the principal source of heavy metals pollution (96% for Pb, 66% for Zn and 56% for Cu) originates from human activities.[2]

Only *Urtica Dioica* seems able to accumulate a higher amount of Pb in leaves (up to 30 ppm in autumn) with respect to the other plants. However, our data suggest that there is not a stringent relationship between soil and roots concentration for each of the heavy metals and plants analyzed. In order to explain these differences, some other variables (soil pH and redox potential, temperature, evapotranspiration, humidity, microbiological composition, etc.) or mechanism (acid-base and redox equilibria, hydrolysis, rainfalls, etc.) should be taken into consideration. Therefore an intensive chemometric analysis should be applied to these data to derive additional information.

**Conclusions**

The main result obtained from these wide analytical study is a close correlation between Pb amount in soil and in *Urtica dioica L.* roots and leaves (R=0.966 and R= 0.951 respectively) suggesting its potential role as a natural bioindicator. Parameters such as soil pH, temperature, humidity, soil and microbiological composition, should be considered in the future together with a chemometric analysis approach to fully illustrate the importance of common plants as natural bioindicators.

**References**

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