BIOACCESSIBILITY OF HEAVY METALS AND RISK ASSESSMENT IN URBAN GARDENS OF MADRID

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INTRODUCTION

Urban agriculture has spread worldwide in recent years as it enhances a sustainable urban development, a greener economy and food security. However, there are also some drawbacks, being of particular concern the risk for human health associated with conducting agricultural practices or the ingestion of food plants grown in urban soils, which are significantly enriched in trace elements due to current or historical activities.

Most soil quality guidelines are based on total concentrations in soil, but they may overestimate dietary risk since only a portion of the elements would be absorbed by the human body or uptake by plants, so there is an increasing interest in incorporating bioavailability into risk assessments models.

For this purpose, during last years *in vitro* extraction tests have been developed to determine oral bioaccessibility, which attempt to simulate the fraction of a substance that is soluble in the gastrointestinal environment and is available for absorption.

Figure 1. Location of sampled urban gardens (•) and corresponding neighborhoods (■)

MATERIALS & METHODS

For this study, 6 urban gardens (Figure 1) were selected from the ReHdMad, a community food growers network. In each site, 6 composite samples were collected from the arable soil layer (0-20 cm).

The pseudototal and bioaccesible trace elements concentrations were determined using aqua regia and a simplified glycine extractable test, respectively. Solutions were analyzed for Co, Cr, Cu, Ni, Pb and Zn by atomic absorption spectrophotometry.

Additionally, main edaphic properties (pH, texture, calcium carbonate and organic matter contents) and major elements concentrations (Ca, Fe, Mn) were determined in order to analyzed their influence on trace metals bioaccessibility.

Average bioaccessibility calculation (x: pseudototal, y: bioaccesible)

$$B_1 = \frac{1}{n}\sum_{i=1}^{n}\frac{y_i}{x_i} \qquad B_2 = \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} x_i} \qquad y = B_3\, x$$

Linear regression assumptions { constant variance of residuals; zero bioaccessibility at zero total concentration

Intake equations

Soil ingestion

$$I = \frac{C \times IR_S \times EF \times ED}{BW \times AT} \times CF$$

Dermal contact

$$I = \frac{C \times SA \times AF \times ABS \times EF \times ED}{BW \times AT} \times CF$$

Dust inhalation

$$I = \frac{C \times EF \times ED}{PEF \times AT}$$

Fruits and vegetables ingestion

$$I = \frac{C \times FCB \times IR_V \times EF \times ED}{AT} \times CF$$

RESULTS & DISCUSSION

- A multiple comparison Tukey's test and a cluster analysis revealed that distribution of pseudototal concentrations of trace elements vary significantly among urban gardens, as a result of previous land uses and the diversity of agricultural practices management.
- Concentrations of Cu, Pb and Zn exceed regional backgrounds levels with enrichment factors of 2.3, 6.3 and 2.2, respectively. Moreover, Pb content is even higher than the permissible value for agricultural soils in Madrid.
- Results of average bioaccessibility obtained with each equation are quite similar (Table 1). The slightly differences are caused because of the higher influence of low values on the estimate using the first two expressions.
- The bioaccessibility of the various trace elements is highly variable, less than 10% for Cr and up to 90% for some values of Pb.
- Organic matter content affects metal bioaccessibility (e.g. Figure 3) and calcium carbonate to a lesser extent. On the other hand, a relationship could not be established with soil pH or texture, probably because of the low variability of this parameters between the urban gardens.

	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
B_1	37,02	4,66	24,62	1,57	40,23	31,61	59,38	21,65
B_2	33,46	6,20	30,50	1,44	40,04	26,84	54,27	19,88
B_3	32,21	8,15	39,43	1,33	39,73	25,37	46,54	16,69

Table 1. Average bioaccessibility (%) of the elements

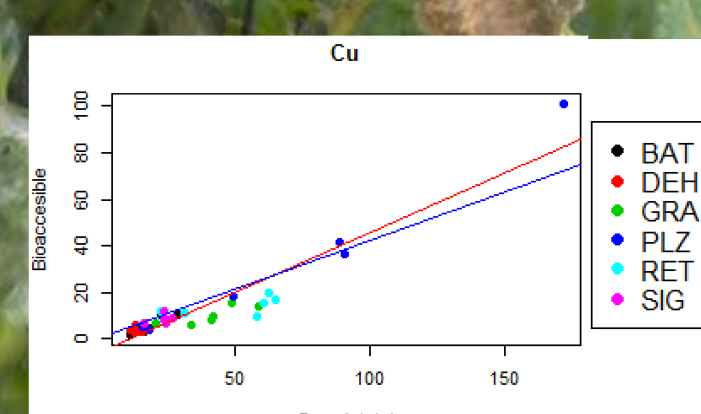

Figure 2. Cu pseudototal vs bioaccesible concentrations (mg/kg)

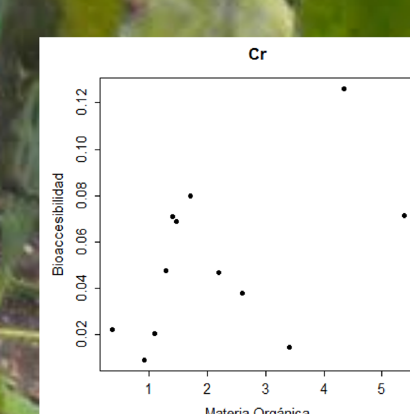

Figure 3. Cr bioaccessibility vs organic matter

- Calculated risk for adult urban farmers and children playing in urban gardens fall below the threshold of unacceptability, but it contributes to the overall risk from exposure to trace elements experienced by those receptors in urban environments.
- Largest contribution to risk:
  - Elements: Pb (85% systemic, ~50% carcinogenic) and Cr (~50% carcinogenic)
  - Routes: grown vegetables ingestion (agricultural) and soil ingestion (recreational)

Table 2. Aggregate Estimate Risk

Toxicity	Risk Characterization		Scenarios: Agricultural (Adults)	Scenarios: Recreational (Children)	Threshold limit value
Systemic	$HI = \sum_i HQ_i$	$HQ = \frac{I}{RfD\ [RfC]}$	0,34	0,14	< 1
Carcinogenic	$P_T = \sum_i P_i$	$P = I \cdot SF\ [UF]$	$7{,}78 \cdot 10^{-6}$	$5{,}29 \cdot 10^{-7}$	$< 10^{-5}$

CONCLUSIONS

- Urban gardens are enriched in the so-called "urban" metals.
- Soil matrix characteristics affects trace elements bioaccessibility.
- Although risk of developing adverse health effects are within acceptable exposure levels, the high degree of uncertainty in bioaccessibility and the heterogeneity of the population and urban garden soils suggests that a site-specific risk assessment should be carried out.

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