Cd, Cu and Zn contents in the leaves of *Taraxacum officinale*

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Abstract
We analysed the contents of Cd, Cu and Zn in the leaves of common dandelion *(Taraxacum officinale)* and in the soil in which the plants were growing, in three different sites: 1) a lightly polluted site on the margin of a landfill, 2) a strongly polluted site on a landfill, and 3) an unpolluted control site. We observed that the metal concentrations in the leaves were at a similar level in all samples and that they did not correlate with the metal concentrations in the soil. A regulation mechanism may adjust the concentrations of the Cu and Zn absorbed or transferred from the roots to the above-ground vegetative parts, to a threshold that probably corresponds to the nutritional demand of the plant. We observed that Cd and Cu concentrations in *Taraxacum* leaves lay under the threshold of those which are admitted by Swiss law for heavy metal contents in food, whereas Zn concentration was slightly above.

Keywords: *Taraxacum officinale,* metal-uptake, soil pollution, food contamination

1 Introduction

Soil pollution is a widespread problem which is recently discussed by many authors. Among inorganic pollutants, heavy metals are a major threat. Metal trace elements represent only a small portion of the solid part of the soil but their influence on its fertility is well known (Kabata-Pendias and Pendias 1992). Their accumulation in soil diminishes soil fertility, microbial activity and plant growth (Lehoczky *et al.* 1996). Moreover, the trace elements are very persistent, can interact by adsorbing to the soil particles and therefore increase the risk of long-term soil pollution and the risk of toxic effects on organisms (Tarradellas *et al.* 1997).

Punz and Sieghardt (1993) distinguished between two groups of metal trace elements. The first group consists of the elements which are necessary to the life of plants and animals (Cu, Fe, Mn, Mo, Zn, Co, Ni and V). The second group includes the non-essential and/or toxic elements (Al, Ag, Cd, Cr, Hg and Pb). Cadmium, an element of this second group, is among the most dangerous metals for humans, due to its strong toxicity (e.g. Itaï-Itaï disease in Japan; Chaney 1990).

The risk of metal pollution in vegetable food depends on the amount that can be absorbed and transferred to the above-ground parts of the plant during growth. This process is limited by the availability of metal pollutants. It is influenced by different factors, including chemistry, soil composition (pH, CEC, granulation, organic matter, Rosselli *et al.* 2003; Kayser *et al.* 2000; Keller *et al.* 1999), climate and plant ability to absorb, translocate and accumulate metal pollutants (Tarradellas *et al.* 1997; Chen *et al.* 2000).

Taraxacum officinale is a very common species, easy to identify and greatly adaptable (Keane *et al.* 2001; Malawska and Wilkomirski 2001). Moreover, this species is commonly collected in spring to be eaten as a salad or used in traditional pharmacopoeia. Therefore, it was interesting to check whether it can accumulate heavy metals at a higher concentration than what is legally admitted in nutritional products in Switzerland. It was also necessary to test whether the degree of metal-pollution in soil is correlated to the metal-concentrations in the leaves of *Taraxacum.* Thus, a possible threshold of the metal-concentrations in the soil could be identified, above which the grass becomes unfit for consumption.

2 Materials and methods

The experimental site is located on a 2-ha landfill for inert waste materials (lime and marl from nearby building areas). Concentrations of heavy metals were very low in these materials (Dubois 1991), but the landfill was capped with a Cd-, Cu- and Zn-polluted final top layer (0.05–0.60 m depth). The average characteristics of this final top layer were: organic carbon 56±1 mg kg^{-1}; pH_{CaCl2} 7.4±0.1; clay 430±130 mg kg^{-1}; sand 300±120 mg kg^{-1} (Rosselli *et al.* 2003). An unpolluted control site was chosen in the vicinity of the perimeter of the landfill.

Taraxacum leaves and soil samples were collected on three sites: one strongly polluted and one lightly polluted, both on the landfill surface, and one non-polluted outside the landfill perimeter (control). Five plots of about 4 m^2 were randomly delimited on each area.

Three soil samples were collected on each plot (45 samples totally). The top 20 cm of the soil was sampled using a Humax auger of ∅5 cm (Max Hug, Luzern, Switzerland). The samples were oven dried at +40 °C for two days, then crushed and sieved to 2 mm through a nylon sieve. Total heavy metal concentrations were determined after digestion with boiling in 2 M HNO_3 (FAC 1989) as required by the Swiss legislation relating to soil (Ordinance Relating to Impacts on the Soil, OIS 1998).

Five *Taraxacum* plants were collected on each plot, adding up to 25 plants per site and 75 in total. After having been rinsed with tap water, the plant samples were dried for four days at 80 °C. The leaves were separately ground in a Rentsch titanium mill, then 0.5 g samples were mineralised in 50 mL tubes with 8 mL HNO_3 65 % s.p. (Merck) and heated till dry. $HClO_4$ was added (1 mL) and samples were further heated at 235 °C for one hour. The clear solution was then made up to 20 mL with purified water (Milli-Q reagent grade water system by Millipore Corporation, Bedford, MA). All glassware or PE-flasks used for digestion and stocking of solutions was soaked in 10 % HNO_3 overnight and rinsed three times with Milli-Q reagent grade water.

Copper, zinc, and cadmium were measured in both, soil and plant samples, by Inductively Coupled Plasma Mass Spectrometry (ICP-MS, HP 4500 Series, Hewlett-Packard). The detection limit was 10×10^{-3} mg kg^{-1}.

3 Results

The metal concentrations in the soil samples are illustrated in Figure 1. There was a significant difference in the mean values: Cd Kruskal $\chi^2_2 = 55.522$, $P < 0.0001$; Cu Kruskal $\chi^2_2 = 55.100$, $P < 0.0001$; Zn Kruskal $\chi^2_2 = 35.927$, $P < 0.0001$

Figure 1 compares these results to the guideline limits of the Swiss federal Ordinance on Impacts on the Soil (OIS) for each one of these metals. The mean Cd concentration in the soil of the strongly polluted site (landfill) is above the legally admitted limits of OIS. Cu and Zn mean concentrations in soil are above the OIS guideline values in both lightly and strongly polluted sites (inside the landfill). Outside the landfill (control area), the concentrations of the three analysed metals were lower than the concentrations admitted by the federal legislation (OIS 1998). These results and previous analyses (data not shown) confirmed that the soil pollution in the area we chose was restricted to the former landfill.

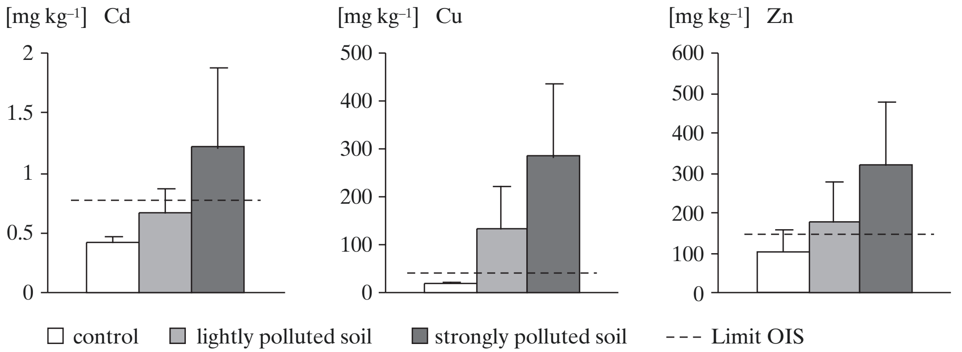

Fig. 1. Mean concentrations of Cd, Cu and Zn in the soil samples from the three different areas. Mean values with standard deviation, N = 15. Different small characters show significant differences of the means. The dashed line shows the guideline concentrations admitted by the Swiss federal Ordinance on Impacts on the Soil OIS (1998).

The metal concentrations in the leaves of *Taraxacum* growing on the delimited areas of the three groups (control, lightly polluted, strongly polluted) were the following:

Cd: Control 0.00±0.00 mg kg^{-1}, N=25; lightly polluted 0.06±0.21 mg kg^{-1}, N = 25; strongly polluted 0.08±0.20 mg kg^{-1}, N = 25.

Cu: Control 11.84±2.48 mg kg^{-1}, N = 25; lightly polluted 12.14±2.16 mg kg^{-1}, N = 25; strongly polluted 11.82±2.19 mg kg^{-1}, N = 25.

Zn: Control 59.94±20.46 mg kg^{-1}, N = 25; lightly polluted 44.06±10.14 mg kg^{-1}, N = 25; strongly polluted 44.70±9.60 mg kg^{-1}, N = 25.

There was no significant difference of the means except for Zn: Kruskal $\chi^2_2 = 19.304$, $P < 0.001$.

The concentrations were measured in dry matter. According to an average water-content of 87.5 % in fresh *Taraxacum* leaves (Jean-Pierre Clément, personal communication), the metal concentration in fresh matter should be adjusted as follows:

Cd: Control 0.00±0.00 mg kg^{-1}, N = 25; lightly polluted 0.007±0.026 mg kg^{-1}, N = 25; strongly polluted 0.01±0.025 mg kg^{-1}, N = 25.

Cu: Control 1.48±0.31 mg kg^{-1}, N = 25; lightly polluted 1.52±0.27 mg kg^{-1}, N = 25; strongly polluted 1.48±0.27 mg kg^{-1}, N = 25.
Zn: Control 7.49±2.56 mg kg^{-1}, N = 25; lightly polluted 5.51±1.26 mg kg^{-1}, N = 25; strongly polluted 5.59±1.2 mg kg^{-1}, N = 25.

These results were to be compared to the Swiss legal guideline limits concerning substances in food (Ordinance on the Substances and Composants of Food OSEC) for each one of these metals. The acceptable concentration of metals in fresh matter according to OSEC is 0.2 mg kg^{-1} Cd; 5 mg kg^{-1} Cu; 5 mg kg^{-1} Zn. The mean Cd and Cu concentrations in the three groups were lower than the legal limit (OSEC 1995). On the contrary, Zn concentration was slightly higher than the limit admitted.

The diagrams showing metal concentrations per dry mass in the plants vs. metal concentrations per dry mass in the soil are given in Figure 2. Our results show that the metal concentrations in the leaves did not correlate with the metal concentrations in the soil samples. No trend between soil and plant metal concentration inside one or the other site (control, lightly polluted, strongly polluted) was detectable (not shown). Thus, the heavy metal concentrations in *Taraxacum* do not depend on their concentrations in the soil. These results do not allow to determine a metal-concentration limit in soils above which the consumption of *Taraxacum* could be prohibited.

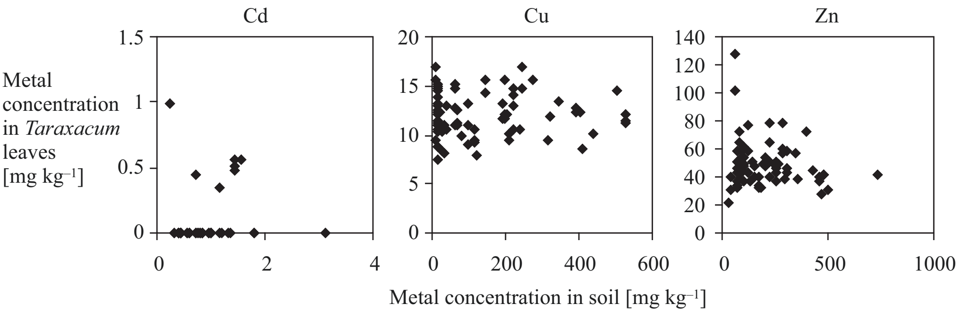

Fig. 2. Concentrations of heavy metals in the leaves of *Taraxacum officinale,* as a function on the concentrations of metals in the soil (both dry mass). No correlation between the metal concentrations in leaves and the concentrations in soil, no trend inside the individual sites.

4 Discussion

The Zn concentration in the leaves of some *Taraxacum* individuals of the control group was slightly higher than in the plants growing on the polluted soil. It was slightly above the legally admitted limit. We can assume that this will not be a problem for public health, due to the small difference between the concentrations measured and the legal limits, and to the low consumption of *Taraxacum*, which is restricted to a very short period in spring.

The lack of correlation between the metal-concentrations per dry mass in soil and in leaves (Fig. 2) supports the hypothesis of a regulation mechanism which adjusts the metal concentrations in the leaves to a given level, e.g. by storage in the root tissues (Khan 2001; Blaylock and Huang 2000; Alloway 1999; Marschner 1995). We assume that this concentration level corresponds to the amount that is naturally absorbed by the plant for nutritional purposes, since Cu and Zn are essential trace elements. On the other hand, the lack of a correlation between the concentrations of metals in the soil and leaves may be due to a too narrow scale of pollution levels, as suggested by MARTIN and COUGHTREY (1982). The latter authors have also shown that genotypical differences in a species may affect the absorption of the metals, although this was not investigated in *Taraxacum officinale.*

Other studies on *Taraxacum officinale* (MALAWSKA and WILKOMIRSKI 2001; KEANE *et al.* 2001; DIATTA *et al.* 2003) showed that the concentrations of heavy metals in the plants depended on their concentrations in the soil, although there were different patterns for the three metals analysed (Cd, Cu and Zn). KEANE *et al.* (2001) and KROLAK (2001) found the same trend we did but only for Zn.

Pedological factors such as mineralogy, soil texture, hydration, aeration, pH, redox potential (Eh), cation exchange capacity (CEC), total organic carbon (TOC) and the interactions between the different metals influence the bioavailability of heavy metals for plants (KABATA-PENDIAS and PENDIAS 1992). In our case, the slightly alkaline pH and the high content of organic matter may affect the mobility and the bioavailability of the metals and their uptake by the plants (ROSSELLI *et al.* 2003). Other environmental factors, such as temperature, influence the metal diffusion and the metabolic processes linked to absorption (GIORDANO *et al.* 1979; KABATA-PENDIAS and PENDIAS 1992). The only parameters that we measured were the pH and the total heavy metal concentration in soil. The first one did not vary in our samples, whereas the second one seemed to be a very poor indicator of the availability of metals for *Taraxacum officinale* (MARR *et al.* 1999). Bacteria and fungi which are present in the rhizospere may have an effect on the absorption of trace elements (ERNST 1996). They seem to alter the solubility of the elements close to the roots by modifying the physico-chemical conditions of the soil and of the processes which determine the bioavailability of the elements. The bioavailability of metals may also be affected by phytostabilisation due to the presence of certain species (ROSSELLI *et al.* 2003), or by their adsorption on the root surface (VANGRONSVELD *et al.* 1995; SMITH and BRADSHAW 1972).

Acknowledgements
The authors wish to thank Elena Rossel and Jean-David Teuscher for laboratory and technical support, Brigitte Corboz-Maier and Edward A. D. Mitchell for both critical and linguistic reading of the manuscript. Alexandre Buttler, Jean Combe, Antoine Guisan, Jean-Paul Schwitzguebel and the teams of WSL Lausanne, the Laboratory of Ecological Systems-ECOS – EPFL and the Spatial Ecology Group of the University of Lausanne are also kindly thanked for scientific support.

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Revised version accepted December 6, 2006