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THE COMMON DANDELION (*TARAXACUM OFFICINALE*) AS AN INDICATOR OF ANTHROPOGENIC TOXIC METAL POLLUTION OF ENVIRONMENT

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Abstract. The common dandelion (*Taraxacum officinale*) is a widely distributed plant, not only geographically but also in terms of diverse, often extremely polluted habitats. It is therefore potentially an ideal plant to study accumulation of anthropogenic pollution. The aim of the study was to determine the suitability of common dandelion to assess the environmental contamination of Cd, Cr, Cu, Fe, Mn, Ni, Pb, Ti, Zn, V. The plants were collected from sites initially identified as significantly polluted as well as habitats presumably hardly contaminated. Analyses were made using inductively coupled plasma optical emission spectrometry (ICP OES) in argon, following decomposition of the organic matrix of samples using a mixture of 65% HNO_3 and 30% H_2O_2 in a microwave digestion system. Elevated levels of Cd, Cr, Cu, Fe, Ni and Ti were found both in the leaves and roots of dandelion collected from more polluted sites. The results show that the common dandelion can be a good bio-indicator of environmental contamination for these elements. For the other studied metals, the results were not so unequivocal. In the case of Cd, Cr, Mn, and Ni, statistically significant correlation was found in the concentrations of these elements between the dry matter of leaves and roots.

Keywords: common dandelion, environment, leaves, metals, roots

INTRODUCTION

Modernity is characterized by dynamic technological development, which is based mostly on mining of fossil fuels, metal ores, minerals used for fertilizer production, and feedstock for other chemical industries. The massive mining and processing of minerals fills the environment with a number of elements and compounds which were previously absent or occurred in small quantities in the form of so-called geochemical background. Introduction of additional quantities of these substances usually turns out to be harmful or toxic to the biosphere. Although life on Earth has some adaptive abilities, it must be kept in mind that the previous evolutionary processes in the biosphere did not occur in the presence of these substances. Imperfectly evolved defense mechanisms in the face of rapid

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growth in the levels of xenobiotics in the environment lead to their accumulation in living organisms and, consequently, to a chronic or acute toxicity, sometimes even leading to death [Kleszczewska and Kaczorowski 2001, Królikowska-Gruca and Wacławek 2006]. Among all the environmental poisons, there is a large group of metals showing toxicity regardless of their concentration in the environment, or those which are harmful beyond a certain level of concentration in the body. Many of these elements have a nutritional value, however only in a limited range of small concentrations. Anthropogenic pollution media carrying these elements can be liquid, gaseous, or dust, and affect all parts of the geosphere: the atmosphere, hydrosphere and lithosphere [Harrison and Yin 2000, Kondej 2007].

An important part in protecting the environment against anthropogenic contamination is its monitoring, including assessing the degree of accumulation of the elements in plants. For this purpose, the best are organisms commonly found in a variety of habitats, less sensitive or insensitive to intoxication, with a wide geographic range of distribution. Examples of such species may be: mosses and lichens [Folkeson 1981, Bargagli 1989, Bargagli et al. 1995], chicory (*Cichorium intybus* L.) [Simon et al. 1996], common dandelion (*Taraxacum officinale*) [Oosterveld 1982, Kuleff and Djingowa 1984, Kabata-Pendias and Dudka 1991, Normandin et al. 1998, Marr 1999, Keane et al. 2001, Diatta et al. 2003] and others. The common dandelion seems particularly useful for this purpose, since it grows wild in all temperate regions of the world, as a ubiquitous weed of gardens, meadows, lawns, road-sides, and ruderal habitats, often growing on strongly polluted sites, such as railway tracks or dusty surrounding of industrial plants.

Several studies have analyzed the concentration of metals in dandelion samples collected at different distances from the source of metal emissions to the atmosphere (eg smelters), where it was found that concentrations of some metals in the tissues of plants growing closer to the source are higher compared with the plants collected farther from the center of emission [Kuleff and Djingova 1984, Djingova et al. 1986, Djingova et al. 1993]. Although these studies have not demonstrated to what extent the common dandelion collects metals from the soil solution and how much it absorbs directly from the atmosphere, but the results suggest that dandelion can be a useful monitoring tool for metal pollution, especially near local point sources emitting relatively high level of elements to the atmosphere. On the other hand, other studies have not revealed a significant relationship between the concentration of many metals in the soil and their content in the plant. Presumably, there is a complex of factors that underlie the dandelion's absorption of metals from the soil. Besides the concentration of metals in the soil, environmental factors play a critical role to metal uptake by the plant [Kabata-Pendias and Dudka 1991, Cook et al. 1994, Marr et al. 1999]. The level of metals in plant tissues can vary seasonally [Crump et al. 1980, Deu and Kreeb 1993]. In studies over the concentration of elements in plants, especially in a comparison of results, one can not ignore the phenological events, having its importance in this respect. With regard to the common dandelion, this issue has been raised only by and Djingova and Kuleff [1994].

This study attempts to determine the usefulness of the common dandelion for assessment of magnitude of environmental contamination with the following metals: Cd, Cr, Cu, Fe, Mn, Ni, Pb, Ti, Zn, V, including their quantitative distribution in the leaves and roots of plants.

MATERIAL AND METHODS

The material used in our study was the common dandelion (*Taraxacum officinale*) collected in 5 measuring points along an expected gradient of anthropogenic pollution. One of those places was located in the center of Szczecin (Rondo Sybiraków), four others were selected from the district of Police (Chemical Plant "Police" and the villages of Tanowo, Brzózki and Myślibórz Wielki).

We chose to study only the elements of a toxic character (Cd, Pb) and those that are harmful at high concentrations in the environment (Cr, Cu, Fe, Mn, Ni, Ti, Zn, V).

Material for analysis was collected on two spring days, three plants of each station. The plants were dug from the earth as a whole, so as not to damage the root system and in this form transported to the laboratory where the roots were separated from the leaves. Both roots and leaves of plants were thoroughly washed in deionized water with a small addition of non-ionic detergent, then rinsed several times (also with deionized water) to the disappearance of foam. Washed plants were placed on sheets of blotting paper for pre-drying, then placed in an oven at 105°C for 24 hours. The dried material was triturated in a porcelain mortar to a dusty form, ensuring uniformity of chemical composition throughout the mass of the sample.

The amounts of 0.5 g for spectrometric assays were digested in the microwave system "Microwave" (Anton Paar) equipped with a system of continuous monitoring and adjustment of the process parameters (pressure and temperature) in each of the quartz vessels. For calibration, one of the procedures integrated with the equipment, for spinach, was used. Oxidant in the process of digestion was a mixture of 65% HNO_3 and 30% H_2O_2 in a ratio of 5:1 v/v. The digestion was carried out at 220°C, at a pressure of 75 MPa for 20 minutes (plus 15 min. for cooling of the system).

The concentration of elements in the material was analyzed by inductively coupled plasma optical emission spectrometry (ICP OES) in argon, using the spectrometer "Optima 2000 DV" (Perkin Elmer).

Certified ICP Multielement Standard VIII solution (Merck) was used for quantification. Working standard solutions were supplemented with the addition of nitric acid to a concentration that occurred in the samples after digestion. In order to further minimize the potential interference of possible physical type in argon plasma, spectrometric analysis was performed using an internal standard, through the introduction of yttrium (Y), at concentrations of 0.5 mg $\cdot$ l^{-1}, to the sample and standard solutions. Measurements were made using the most intense, most recommended for each element emission lines, with a longer, axial optical path in the plasma.

The results of chemical analysis were statistically analyzed using nonparametric procedures of the package Statistica®, namely the Kruskal-Wallis test, the equivalent of ANOVA, and Kendall's tau test, the non-parametric correlation coefficient.

RESULTS AND DISCUSSION

The concentration of the studied metals in the roots and aerial parts of the common dandelion are shown in Tables 1 and 2.

In the vast majority of cases, the concentrations of the elements in the dry matter of leaves were higher than in roots. The same regularity was found by Kabata-Pendias and Dudka [1991] for Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn.

Table 1. The content of chemical elements in common dandelion roots, mg · kg^{-1} d.m.
Tabela 1. Zawartość pierwiastków w korzeniach mniszka pospolitego, mg · kg^{-1}s.m.

	Z.CH. Police		Rondo Sybiraków		Tanowo		Myślibórz Wielki		Brzózki	
	mean średnia	SD	mean średnia	SD	mean średnia	SD	mean średnia	SD	mean średnia	SD
Cd	0.0216 ^{A}	0.00029	0.0217 ^{A}	0.00004	0.0179 ^{B}	0.00024	0.0180 ^{B}	0.00038	0.0143 ^{C}	0.00131
Cr	0.219 ^{A}	0.0043	0.204 ^{A}	0.0009	0.160 ^{B}	0.0004	0.165 ^{Ba}	0.0047	0.159 ^{Bb}	0.0051
Cu	14.74 ^{Aa}	0.164	12.18 ^{Ab}	0.176	8.53 ^{B}	0.067	4.92 ^{C}	0.076	8.94 ^{B}	0.232
Fe	289 ^{A}	6.7	304 ^{A}	8.0	100 ^{Ba}	1.7	154 ^{Bb}	4.6	118 ^{Ba}	4.5
Mn	12.2 ^{A}	0.46	10.6 ^{A}	0.28	10.0 ^{A}	0.11	34.8 ^{B}	0.39	50.3 ^{C}	2.32
Ni	0.203 ^{A}	0.007	0.204 ^{A}	0.056	0.133 ^{Ba}	0.006	0.155 ^{Bb}	0.004	0.215 ^{A}	0.007
Pb	0.167 ^{A}	0.00562	0.207 ^{Ba}	0.00528	0.173 ^{A}	0.00054	0.216 ^{Ba}	0.00286	0.242 ^{Bb}	0.00899
Ti	13.05 ^{A}	1.264	7.62 ^{Ba}	0.341	4.22 ^{C}	0.447	8.77 ^{Bb}	0.176	4.70 ^{C}	0.150
Zn	40.2 ^{Aa}	1.31	60.9 ^{B}	0.12	36.3 ^{Ab}	0.05	30.5 ^{Ab}	7.55	64.2 ^{B}	1.70
V	0.444 ^{A}	0.002	0.380 ^{Ba}	0.007	0.348 ^{Bb}	0.004	0.455 ^{A}	0.009	0.391 ^{Ba}	0.014

Mean values marked with different letters in row differ significantly at P≤0.01 (capital letters) and P≤0.05 (small letters).
Średnie oznaczone różnymi literami w wierszu różnią się istotnie przy P≤0,01 (duże litery) i przy P≤0,05 (małe litery).

The concentrations range of a given element in plants often involves two or more orders of magnitude [Kabata-Pendias and Dudka 1991], depending on the location from which the material was sampled. A number of interrelated factors underlie this effect, often non-comparable or unknown, thus a confrontation of the resulting concentration ranges with literature data is difficult.

The ranges of concentrations found in leaves from the Szczecin agglomeration for Mn, Cu, Zn, Cr, Fe and Ni were respectively: 18.9–68.5, 6.88–15.22, 24.6–84.1, 0.19–1.039, 209–703 and 0.172–0.580 mg · kg^{-1} of dry matter, and were similar to those reported for dandelion by Kabata-Pendias and Dudka [1991], and Marr et al. [1999], Diatta et al. [2003]. Also in relation to the roots of dandelion from Szczecin and its surroundings, there was a substantial compliance between our results and the results of Kabata-Pendias and Dudka [1991]. The level of cadmium and lead, both in leaves and roots of dandelion from the agglomeration of Szczecin, was low and amounted, respectively, 0.0155–0.0206 and 0.173–0.241 (in leaves) and 0.0143–0.0217 and 0.167–0.242 (in roots) mg · kg^{-1} dry matter. Diatta et al. [2003] reported much higher concentrations of cadmium and lead in the leaves of this plant from the area of Poznan, i.e. 0.6–1.4 and 1.7–6.2 mg · kg^{-1} dry matter, respectively. In the leaves of dandelion collected from the highly developed urban area of Montreal, Marr et al. [1999] found from 0.08 to 1.05 mg · kg^{-1} d.m. of cadmium and from 5.83 to 6.80 mg · kg^{-1} d.m. of lead.

We did not find in the available literature relevant comparative information concerning the content of titanium and vanadium in the common dandelion.

Table 2. The content of chemical elements in common dandelion leaves, mg · kg^{-1} d.m.
Tabela 2. Zawartość pierwiastków w liściach mniszka pospolitego, mg · kg^{-1}s.m.

	Z.Ch. Police		Rondo Sybiraków		Tanowo		Myślibórz Wielki		Brzózki	
	mean średnia	SD	mean średnia	SD	mean średnia	SD	mean średnia	SD	mean średnia	SD
Cd	0.0204^{A}	0.00001	0.0206^{A}	0.00028	0.0163^{B}	0.0004	0.0166^{B}	0.00035	0.0155^{B}	0.00047
Cr	1.039^{A}	0.0062	1.000^{A}	0.0141	0.370^{Ba}	0.0021	0.334^{Bb}	0.0094	0.190^{C}	0.0021
Cu	6.88^{A}	0.002	15.22^{B}	0.463	11.07^{Ca}	0.190	9.84^{Cb}	0.004	10.73^{Cab}	0.130
Fe	460^{A}	6.2	703^{B}	10.6	336^{Ca}	4.7	316^{Cb}	5.0	209^{D}	1.4
Mn	18.9^{Aa}	0.31	27.6^{Ab}	0.48	28.5^{Ab}	0.30	51.7^{B}	2.12	68.5^{B}	0.92
Ni	0.580^{A}	0.010	0.580^{A}	0.002	0.172^{Ba}	0.002	0.189^{Bb}	0.022	0.267^{C}	0.005
Pb	0.190^{Aa}	0.00113	0.241^{B}	0.00121	0.199^{Aa}	0.0039	0.209^{C}	0.00048	0.173^{Ab}	0.00670
Ti	28.17^{A}	0.963	21.38^{B}	0.570	15.72^{Ca}	0.835	16.32^{Cb}	0.722	11.71^{Cc}	0.030
Zn	24.6^{Aa}	0.06	69.8^{B}	0.05	29.7^{Ab}	0.87	44.8^{C}	0.39	84.1^{D}	1.69
V	0.398^{Aa}	0.006	0.370^{Ab}	0.013	0.343^{ABc}	0.006	0.377^{Aab}	0.009	0.299^{B}	0.001

Mean values marked with different letters in row differ significantly at $P \leq 0.01$ (capital letters) and $P \leq 0.05$ (small letters).
Średnie oznaczone różnymi literami w wierszu różnią się istotnie przy $P \leq 0{,}01$ (duże litery) i przy $P \leq 0{,}05$ (małe litery).

In many cases, the average level of the studied metals (Cd, Cr, Cu, Fe, Ni and Ti), both in the roots and leaves of dandelion coming from places with more intense anthropogenic pollution (Chemical Plant "Police", Rondo Sybiraków), was statistically significantly higher ($P \leq 0.01$ and $P \leq 0.05$) than in the other areas. These metals often find industrial application, including the manufacture of everyday objects. When used up, the objects are not always properly disposed of, and their residues, often corroded, pollute the surrounding. The remarkable fact is the the concentration of titanium in the material collected in the Police, about twice as high as in the other sites. Undoubtedly, this is associated with the production of titanium dioxide by the "Police" Chemical Plant. Another situation was found for manganese, whose higher content in leaves and roots of this plant was reported from the places initially considered to be less polluted (Myślibórz Great, Brzózki). This may result from the characteristic geochemical background of the area. Another reason may be the soil physicochemical parameters, especially pH and redox potential, determining the mobility and extraction of minerals by the plants from the substrate [Masscheleyn 1991].

In all the studied places, there were generally low levels of lead in the dandelion, also in that which came from the center of Szczecin, although many significant differences

(P≤0.01 and P≤0.05) between the various sites were found in both leaves and roots. Small concentrations of Pb in plants from areas where one could expect a higher content of this metal, can be explained by the elimination of the leaded gasoline years ago, limited number of coal-fired heating installations in developed areas, as well as the establishment of urban green areas based on a mixture of uncontaminated soil supplied from outside the city.

In the dandelion roots collected from more polluted sites, only Cu content was higher. The leaf dry matter varied considerably in terms of metal concentration, lacking any regularity. Also the levels zinc in the eaves and roots were variable.

Vanadium primarily comes from burnt fossil fuels, especially petroleum products and coal [Morrell et al. 1986]. In our study, vanadium had a fairly balanced concentration in the dandelion, however slightly higher and significantly different from the value of the plants more vulnerable to road traffic fumes. Higher content of vanadium found in dandelion in Myślibórz Wielki, as was the case of previously discussed manganese, can be explained by geochemical specificity of the habitat and a significant mass of organic matter in the soil, to which the metal has a strong affinity [Morrell 1986].

Table 3 presents the correlation coefficients between the content of the analyzed elements in the leaves and roots.

Table 3. The Kendall tau rank correlation coefficient between the content of chemical elements under examination in leaves and that in roots
Tabela 3. Współczynniki korelacji tau Kendalla między zawartością badanych pierwiastków w liściach oraz w korzeniach

Cd	Cr	Cu	Fe	Mn	Ni	Pb	Ti	Zn	V
0.94*	0.98**	0.10	0.86	0.97**	0.69*	0.02	0.88	0.86	0.57

Correlation coefficients marked with ** and * represent significance, respectively at P≤0.01 and P≤0.05.
Wartości współczynników korelacji oznaczone ** oraz * oznaczają istotność, odpowiednio przy P≤0,01 i P≤0,05.

Only in the case of copper and lead, there was no relationship between the concentration of these metals in both morphotic parts of dandelion. In higher plants, lead is accumulated mainly in the endoderm cells [Woźny 1998], resulting in a reduction in its metabolism and transport. Dalenberg and Van Driel [1990] found, however, that lead precipitating from the atmosphere is transferred to the grass roots, which show its increased concentration. The level of copper in roots is also higher than that in the green parts and, like lead, copper in higher plants is characterized by slow migration [Yruela 2005]. Lack of correlation between Cu and Pb content in leaves and roots, with a greater concentration of these metals in the roots, especially copper, suggests better suitability of the roots of the plants to monitor contamination of the environment of these elements. In this regard, high and statistically significant correlation coefficients were observed for chromium and manganese (P≤0.01) and for cadmium and nickel (P≤0.05). This indicates a strong positive relationship between the content of these components in the root and green parts of plants.

Most likely, such relationships also exist with respect to iron, titanium, vanadium and zinc, since the correlation coefficients in these cases proved to be high. However, we failed to confirm their statistical significance, probably due to too a small sample size.

Proportional distribution of concentrations of elements in different morphotic parts of the plant, expressed in mathematical relations, may have some practical importance in selecting and preparing plant material for chemical assay. In cases where such correlations exist, dandelion leaves appear to be a better material, easier to collect, especially from well-maintained urban squares. Samples of leaves are also less laborious in preparation and give greater certainty of accuracy. Leaves are easier to wash from external dirt, dry faster, and are easier to grind to obtain homogeneous material. In most cases, a greater concentration of elements (Cr, Cu, Fe, Mn, Ni, Pb, Ti) was found in the dry matter of leaves compared to that in roots. This is advantageous because of the accuracy and precision of the measurements, especially when the elements are present in ultra-trace quantities in the sample, which limits the use of a number of less sensitive analytical techniques available in the laboratory.

CONCLUSIONS

We demonstrated a statistically significant relationship between the concentrations of chromium, cadmium, copper, nickel, titanium, and iron in the leaves and roots of the common dandelion and the degree of habitat pollution, from which the samples were collected, which allows the use this plant for bio-indication of environmental pollution with these elements.

With respect to chromium, cadmium, manganese, and nickel, statistically significant correlations were found between their content in the dry matter of leaves and roots. Such dependencies gives us the choice to study the morphotic part of the plants, of which both pretreatment and the entire process of quantitative analysis are more convenient.

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WYKORZYSTANIE MNISZKA LEKARSKIEGO (*TARAXACUM OFFICINALE*) DO OCENY ANTROPOGENICZNEGO ZANIECZYSZCZENIA ŚRODOWISKA METALAMI TOKSYCZNYMI

Streszczenie. Mniszek pospolity (*Taraxacum officinale*) jest rośliną bardzo rozpowszechnioną nie tylko geograficznie, lecz także pod względem różnorodności siedlisk, często niezwykle silnie zanieczyszczonych. Jest zatem rośliną potencjalnie idealną do badań nad kumulacją zanieczyszczeń antropogenicznych. Celem badań było ustalenie przydatności mniszka pospolitego do oceny skażenia środowiska naturalnego Cd, Cr, Cu, Fe, Mn, Ni, Pb, Ti, Zn, V. Rośliny pobrano z miejsc wstępnie uznanych za znacznie skażone oraz z siedlisk przypuszczalnie mało zanieczyszczonych. Analizy wykonano metodą spektrometrii emisyjnej ze wzbudzeniem w indukcyjnie sprzężonej plazmie argonowej (ICP OES), po dekompozycji osnowy organicznej próbek mieszaniną 65% HNO_3 i 30% H_2O_2 w mineralizatorze mikrofalowym. Zarówno w liściach, jak i w korzeniach mniszka pobranego z miejsc bardziej zanieczyszczanych stwierdzono podwyższony poziom Cd, Cr, Cu, Fe, Ni i Ti. Uzyskane wyniki wskazują, że mniszek pospolity może być dobrym bioindykatorem skażenia środowiska tymi pierwiastkami. W odniesieniu do pozostałych badanych metali wyniki nie okazały się tak jednoznaczne. W przypadku Cd, Cr, Mn, i Ni wykazano występowanie statystycznie istotnych korelacji między zawartością tych pierwiastków w suchej masie liści i korzeni.

Słowa kluczowe: korzenie, liście, metale, mniszek pospolity, środowisko

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