Useful Phytoindicator (Dandelion) for Trace Metal Pollution

Alina Kabata-Pendias and Andrzej Krakowiak
Institute of Soil Science and Plant Cultivation (IUNG)
Pulawy, Poland

Introduction. Bioindicators are organisms with a relatively high ability to accumulate several or specific chemical elements. Among phytoindicators, dandelion (*Taraxacum officinale*, Web.) fulfills most of the requirements as a useful plant in the investigation of trace metal pollution. It is a widespread perennial herb in various ecosystems and under differentiated climatic conditions. Simultaneous collection of leaf and root samples gives a possibility of distinguishing atmospheric from soil-borne metals.

Several studies carried out with various phytomonitors have indicated a great feasibility of using the common dandelion plant around the world (1, 2, 5, 9). The Coefficient of Specific Relative Accumulation (CSRA) proposed by Lambert et al. (7) and modified by Kabata-Pendias and Krakowiak (6) was adopted for the assessment of the accumulation of trace metals by different plants (Table 1). CSRA values clearly indicate significantly greater uptake of Cd, Cu, Mn, Pb, Zn, and Fe by dandelion than by other candidate plants.

Table 1. Coefficient of Specific Relative Accumulation (CSRA)[a] of the Elements by Plants Grown under the Same Conditions (after Kabata-Pendias, 2)

Plant	Cd	Zn	Pb	Cu	Mn	Fe
Dandelion *Taraxacum officinale Web.*	3.42	6.80	4.04	2.60	8.43	2.72
Plantain *Plantago major* L.	0.93	0.54	0.57	0.89	0.23	0.85
Bromegrass *Bromus uniloides* L.	0.11	0.09	0.26	0.52	0.06	0.49
Acacia *Robinia pseudoacacia* L.	1.49	0.25	1.33	1.02	0.49	0.76
Horse Bean *Vicia faba minor* L.	0.23	0.45	0.27	1.49	0.82	0.71

[a] CSRA value is calculated as a ratio of the content of an element in a given plant to the average content of this element in all other plants grown in the same site (or pot)

Although *Taraxacum officinale* is known to exist in a number of microspecies, and is an apomixis plant, the research done by Djingova and Kuleff (1) suggests that the variation in metal uptake is negligible. This is also supported by the similarity of background metal concentrations calculated for dandelion leaves in Bulgaria, Poland, and USA (1, 4, 8).

Materials and Methods. Several studies were carried out with dandelion (2-6). In the last project, dandelion plants (leaves and roots) were collected in 1993 and 1994 from the whole territory of Poland, at the same stage of development, during two weeks of May. Air-dried plants were ashed at 450° C, dissolved in HCl (C=6 mol/L) and analyzed for metals by AAS spectroscopy. Cd and Pb were measured after organic extraction with APDC/MIBK. Analytical errors estimated, using reference materials and multiple analyses, varied from 5-20% depending upon the metal.

Results and Discussion. Plants grown in the southwestern (SW) industrial region contained significantly higher amounts of metals than average values calculated for the whole country, and more than plants grown in the other regions (Table 2). Especially, values of the Relative Deviation to Constant (RDC) calculated against the average metal concentrations in dandelion from three countries (Bulgaria, Poland and USA) show increased levels of metals in dandelion grown in the SW region of Poland. The ratio of metals in leaves to roots, however, is a more sensitive indicator and clearly indicates areas where there is an increased atmospheric deposition of trace metals (6). This phenomena is also observed for light metals; e.g., Li average content in dandelion leaves in the industrial region (SW) are 6.3 mg/kg, and ratio of leaves to roots is 5.0 mg/kg, whereas these values for the rural region (NE) are respectively 0.7 mg/kg and 0.8 mg/kg (3).

Table 2. Metals in Leaves of Dandelion Grown in Different Regions of Poland (mg/kg dry weight)
(N = Number of samples taken)

Metal[a]	Country N=780	All Regions N=60	Region SW N=60	Region SE N=70	Region NW N=60	Region NE N=50
Cd	0.5 -20	0.6 0	1.2 50	0.6 0	0.5 -20	0.4 -50
Cu	9.4 -27	9.4 -22	13.4 10	10 -20	8.4 -42	7 -71
Cr	0.8 25	0.8 25	0.7 14	1.3 53	0.7 14	0.4 -50
Mn	60 0	65 7	74 18	103 41	69 13	42 -18
Ni	3.4 50	1.3 -53	4.2 52	6.4 68	3.1 35	1.9 -5
Pb	1.1 -81	1.2 -66	3 33	1 -100	1 -100	0.5 -300
Zn	45 0	50 10	72 37	67 32	35 -28	40 -12
Fe	241 64	261 67	525 83	526 83	218 61	103 17

[a] Upper values for metals are geometric means, and lower values are RDC – Relative Deviation to Constant Values, RDC = {[AM – RF] / RF} x 100.
RF – Reference Contents (mg/kg d.w.): Cd 0.6, Cr 0.6, Cu 12, Mn 60, Ni 2, Pb 2, Zn 45, Fe 85.

The dandelion plant was used to observe trace metal pollution in Warsaw. Metal concentrations in leaves of dandelion grown in the area of Warsaw were lower than the reference constant value (RF) accepted for the "world" dandelion (Table 3). Only Pb was significantly increased in the tops, also when compared to its content in the roots. The other metals, e.g., Mn, Ni, Zn, and Fe, were also at higher concentrations in the tops than in the roots of the dandelion. This may indicate both physiological effects, as probably in the cases of Mn and Fe, and the impact of pollution, as in the cases of Pb, Zn, and Ni.

Table 3. Trace Metals in Leaves of Dandelion Grown in the City of Warsaw and Surroundings (mg/kg dry wt.)

Metal	Parameter[a]	Whole Area N=22	Surroundings N=9	City N=13
Cd	AM	0.42	0.48	0.38
	RDC	-42	-42	-58
	L/R	0.60	0.46	0.73
Cr	AM	0.69	0.51	0.81
	RDC	13	-17	25
	L/R	0.60	0.47	0.70
Cu	AM	10.4	8.5	11.4
	RDC	-15	-41	-5
	L/R	0.58	0.64	0.54
Mn	AM	56	77	41
	RDC	-6	22	-46
	L/R	1.38	1.04	1.63
Ni	AM	4.2	3.5	4.3
	RDC	52	42	53
	L/R	1.05	1.00	1.08
Pb	AM	1.7	1.61	2.4
	RDC	-18	-25	16
	L/R	0.94	0.49	1.26
Zn	AM	58	57	59
	RDC	22	21	23
	L/R	0.87	0.49	1.26
Fe	AM	150	125	325
	RDC	43	32	73
	L/R	0.85	0.95	1.34

[a] Parameters:
AM – arithmetic mean
RDC – relative deviation to constant values, RDC = {[AM – RF] / RF} x 100]
L/R – leaves-to-roots ratio.

The data for Cd, Cr, Cu, Mn, Ni, Pb, Zn and Fe in dandelions growing in different areas of the country show a significant variation. The highest concentrations (geometric mean, mg/kg d.w.) of some metals (Cd 1.2, Ni

4.2 and Pb 3.0) were in leaves of plants from the SW region (industrialized) and the lowest ones (Cd 0.6, Ni 1.7, Pb 0.9) in plants from the NE region (agricultural). This trend is also observed in the distribution of metals in plant roots. A relative accumulation, as compared to the reference plant, of all the metals is higher in roots than in leaves of plants from the SW area. However, leaves of plants from the NE area contain less metals, by a factor from 10 to 100%, than the reference values and than the average values for the whole country. It is an evidence that in the SW area dandelions take up trace metals from both sources, air and soil, while in the NE area the main source of metals is soil.

In the city of Warsaw a predomination of airborne over soil-borne Pb and Zn was observed. The highest relative concentration of Cd in dandelion leaves versus soil Cd, as compared to other metals, was also noted.

The chemical status of the dandelion plant is influenced by a number of biotic and abiotic factors, and therefore it is not simple to assess environmental pollution based on the one bioindicator. However, multifunctional analyses, e.g., of dandelion leaves, roots and soils, are potentially the most useful in environmental studies.

References

1. Djingova, R. and Kuleff, I. 1993. Monitoring of heavy metal pollution by *Taraxacum officinale*. In: Markert B., Ed. *Plants as Biomonitors: Indicators for Heavy Metals in the Terrestrial Environment*, 435-460, VCH, New York.
2. Kabata-Pendias, A. 1977. Accumulation of heavy metals by plants grown on gangue slurries of a copper mine. *Rocz. Glebozn*. 28, no 2, 141-154 (in Polish).
3. Kabata-Pendias, A. 1995. Biogeochemistry of lithium. *Proceedings of Int. Symp. Lithium in the trophic chain: soil-plant-animal-man*. Warsaw, 9-15.
4. Kabata-Pendias, A. and Dudka, S. 1991. Trace metal contents in *Taraxacum officinale* as a convenient environmental indicator. *Environ. Geochem. Health*, 13, 108-112.
5. Kabata-Pendias, A, Galczynska B. and Dudka, S. 1989. Baseline zinc content of soils and plants in Poland. *Environ. Geochem. And Health*, 11, 19-24.
6. Kabata-Pendias, A. and Krakowiak, A. 1995. *Taraxacum officinale* Weber, as phytoindicator for the environmental distribution of trace metals. *Proceedings of the 5th Polish Conference on Analytical Chemistry*. Gdansk, 1, 107.
7. Lambert, J., Denudt, G. and Van Oudenhove, C. 1973. Aspect ecologiques et phytosociologiques de l'analyse minerale des herbages. *Revue d'Agriculture* 4, 893-908.
8. Rule, J.H. 1993. Feasibility of using the common dandelion plants, *Taraxacum officinale* Weber, as an environmental indicator in assessing the trace metal content of soils. *Abstr. Sec. Int. Conf. Biogeochem. Trace Elements*. 206, 103.
9. Rule, J.H. 1994. Use of small plants as trace element phytomonitors, with emphasis on the common dandelion, *Taraxacum officinale*. In: Adriano, D.D., Zueng-Sang Chen and Shang-Shyng Yang, Eds. *Biogeochemistry of Trace Elements*, Science and Technology Letters, Bradford. 627-654.

Questions & Answers: Useful Phytoindicator (Dandelion) for Trace Metal Pollution

Q. TOM BOBER (Eastman Kodak): I have two questions. First of all, did you make any measurements at all of silver? I know you didn't do it across the matrix, but did you encounter silver at all in your measurements? And secondly, is there any land application of sludge used in any of these areas that you were talking about - of sewage sludge from sewage treatment plants?

A. Well, I haven't done measurements in this project for silver, but silver was measured in soil and in bottom sediments, river sediments, in my country within a project which was funded by The Geological Survey. So I can tell you that in soil, silver was a little bit increased but only about 1 ppm in soil. And in this area, southwestern Poland, there are a number of copper mines, lead and zinc mines and smelter operations. So there is a visible increase in soil silver but much more visible increase, up to 100 ppm at one site, in bottom sediments. So bottom sediments seem to be an indicator for special differentiation of silver in soil. You ask about sewage sludge? Do we use or do we distribute sewage sludge?

Q. Yes.

A. Yes, we do, and if you want to hear some results maybe tomorrow I will mention them. But yes, we do. But we have some regulations for that.

Q. ARUN MUKHERJEE (University of Helsinki-Finland): Professor Kabata-Pendias, I'm very astonished that you didn't mention anything about a moss indicator. Do you think that your dendrite indicated metals better than moss? Because here in your indicator you can find out metals from the atmosphere as well as from the soil. But moss has no roots, and in the moss I can only find out, at most, the atmospheric presence of a trace element. Do you have some comments on this?

A. Yes, I do have. And I do believe that the dandelion is a better phytoindicator worldwide than moss. And I will tell you, it reminds me of a previous discussion I had with Germund Tyler from Lund in Sweden, who did very broad studies with moss and was surprised that I did not. Yes, I had such a project, and when I went down to my country, close to industrialized regions, there were not mosses and there were not lichens! So how I could make a study of bioindication? And people even from the country you are now from, I mean from Finland yes, but I mean all Scandinavian countries, they can hardly believe that there are some other environments in the world where moss and lichens do not exist! *(laughter)* So that's my explanation.