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Research Article

Metal Content in Dandelion (*Taraxacum officinale*) Leaves: Influence of Vehicular Traffic and Safety upon Consumption as Food

Agnese Giacomino,[1] Mery Malandrino,[2] Maria Laura Colombo,[1] Sergio Miaglia,[3] Pietro Maimone,[4] Sebastiano Blancato,[3] Eleonora Conca,[2] and Ornella Abollino[2]

[1]*Department of Drug Science and Technology, University of Torino, Via Giuria 9, 10125 Torino, Italy*
[2]*Department of Chemistry, University of Torino, Via Giuria 5, 10125 Torino, Italy*
[3]*Food Safety and Nutrition Service, Local Health Authority CN1, Via Lancimano 9, 12045 Fossano, Italy*
[4]*Food Safety and Nutrition Service, Local Health Authority CN2, Via Vida 12, 12051 Alba, Italy*

Correspondence should be addressed to Mery Malandrino; mery.malandrino@unito.it

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The widespread distribution of the common dandelion, that is, *Taraxacum officinale*, along with its ability to tolerate a wide range of environmental conditions, makes this plant a good candidate as biological monitor of environmental metal contamination. *Taraxacum officinale* leaves growing spontaneously in meadows and along the streets are traditionally picked up and eaten in Italy as salad, so it is important to know the concentrations of potentially toxic elements contained in them from the point of view of food safety. For these reasons the concentrations of Cd, Cr, Cu, Fe, Mn, Pb, and Zn were determined in dandelion leaf and underlying soil samples collected at 12 sites in the province of Cuneo (Piedmont, Italy) in the vicinity of streets or roundabouts. The concentrations were compared with reference values for plant and soils and with maximum allowable concentrations in edible vegetables. Neither dandelion nor soil samples were found to be polluted by metals, but the comparison with limits for vegetables suggests that caution should be used in consuming spontaneously growing vegetables.

1. Introduction

The influence of global or local environmental pollution is to a certain extent reflected by every organism living in a polluted environment. Among inorganic pollutants, a number of elements such as cadmium, copper, and lead can be harmful to plants and humans even at quite low concentrations. In general, heavy metals are not biodegradable and therefore can accumulate in human vital organs. This situation leads to progressive toxic effects [1].

Soils contain trace elements of various origins: lithogenic elements are directly inherited from lithosphere (mother material); pedogenic elements are of lithogenic origin also, but their concentration and distribution in soil layers and soil particles are changed due to pedogenic processes; and anthropogenic elements are all those deposited into soils as direct or indirect results of man's activities. It is well known that generally the phytoavailability of anthropogenic metals in soils is significantly higher than that of naturally occurring metals. Thus, it is most likely that, under similar soil conditions, both lithogenic and pedogenic trace elements will be less mobile and less bioavailable than anthropogenic ones [2].

Since many plants have the tendency to assimilate metals from their surroundings, several species have been evaluated for their utility as biological monitors of environmental metal pollution [3–6]. A good biological monitor should be a species that is represented by large number of individuals over a wide geographic area and has a broad tolerance to metals and accumulates them at levels reflecting those present in the environment, so that its chemical composition will provide a measure of the magnitude of contamination when assessed against background values [4, 7–9].

Leafy vegetables accumulate large amounts of heavy metals because they absorb them in their leaves. Dandelion (*Taraxacum officinale* Weber *sensu lato*) is a particularly attractive candidate for biological monitoring at global level. It is a plant producing new leaves every year; it is widely distributed in both native and agricultural ecosystems and is also known as a good trace metal accumulator [10, 11]. Dandelion has been used in a number of regional-scale studies as a biomonitor of environmental pollution, for example, in Bulgaria [12, 13], Poland [14], Hungary [15], USA [10], Germany [16], and Canada [17]. Some studies revealed a correlation between the pollution level of a given element in an environmental compartment (air, soil,. . .) and the concentration of such element in the tissues of this plant [12, 14, 18], while other studies did not observe such relationship [5, 17]. The determination of metals levels in dandelion sampled at different distances from point sources of metal pollution, for example, smelters, showed that most tissue metal concentrations were distance-dependent, with plants growing closer to the pollution source having levels compared to those growing farther away [5, 12].

Food safety is the basis for the prevention of several diseases. Correct agricultural and sanitary policies are necessary in order to minimize the consumption of contaminated food. In the case of vegetables, whereas the products sold in markets, supermarkets, or shops are monitored and controlled or at least can be controlled with relative ease, spontaneous vegetables are not subject to any inspection. *Taraxacum officinale* is traditionally picked up by people in Italy and eaten as salad. Moreover, it is used as a medicinal plant. In many cases dandelion is collected in fields close to roads with heavy traffic. Car traffic is a considerable source of heavy metals [20, 21], which are believed to be very dangerous roadside pollutants [22, 23]. In addition to lead and cadmium, believed to be an inseparable part of dust issued by motor vehicles, zinc and copper are among the most common soil and vegetation pollutants in the area of communication routes [24].

A prolonged consumption of such plants, containing heavy metals at toxic concentrations, may cause a chronic health hazard. For these reasons we determined the metal contents in *Taraxacum officinale* leaves grown in traffic-impacted areas, with the aim of investigating the effect of vehicular traffic on the level of potentially toxic elements in this plant and the possible harmful effects on human associated with its consumption as food. We determined the concentrations of Cd, Cr, Cu, Fe, Mn, Pb, and Zn, focusing our attention in particular on Cd and Pb, in leaves of dandelion and in the underlying soils in 12 sites in the province of Cuneo, Piedmont, Italy. A further sample was collected in a nearby Natural Park to compare the results obtained with the metal concentrations in an area not affected by vehicular traffic. Finally, the capability of *Taraxacum officinale* to accumulate heavy metals was valued by calculating accumulation factors, namely, biological accumulation factor (BAF) and metal accumulation index (MAI). The data were treated with chemometric techniques to better value the effect of the different stresses on the considered plants.

For the sake of completeness, also the concentrations of some polycyclic aromatic hydrocarbons (PAHs) were determined in a sample subset. Polycyclic aromatic hydrocarbons (PAHs) are formed by the incomplete combustion of organic material from both natural and anthropogenic processes such as volcanic eruption, coal pyrolysis, and oil cracking. PAHs are ubiquitous contaminants that are released into the environment through industrial processes such as wood treatment facilities, household heating, road transport [25], and gas manufacturing plants [26].

Several PAHs have been classified by the International Agency for Researches on Cancer as probable or possible human carcinogens. The US Environmental Protection Agency (EPA) regulates sixteen PAHs as priority pollutants, seven of them being recognized as carcinogens. Certain PAHs are also classified as persistent organic pollutants (POPs) and persistent bioaccumulative chemicals [27]. The selected PAHs are naphthalene (Naph), acenaphthylene (Ac), acenaphthene (Ace), 9H-fluorene (Flu), phenanthrene (Phe), anthracene (Anth), fluoranthene (Fluo), perylene (Pery), tetraphene (Tet), chrysene (Chr), benzo[b]fluoranthene (BaFl), benzo[k]fluoranthene (BkFl), benzo[*pqr*]tetraphene (BaPy), benzo[k]tetraphene (BaTet), benzo(g,h,i)perylene (BaPery), and indeno[1,2,3-cd]pyrene (InPy) [28].

This research study was performed within the framework of cooperation between the University of Torino and the Food Safety and Nutrition Service of two local health authorities of the province of Cuneo (Piedmont, Italy). To the best of our knowledge, this is the first attempt to investigate dandelion as biological monitor to establish correlation between trace metal pollution and vehicular traffic in Piedmont region and the possible risks associated with the consumption of this vegetable.

2. Material and Methods

2.1. Sample Collection and Pretreatment. The samples were collected in the province of Cuneo, in Piedmont, Italy (Figure 1). Twelve sites (coded 1–12) were considered for the study, as shown in Table 1. The investigated area is mostly rural, but it is crossed by a lot of provincial and national roads with intense vehicular traffic. In this study, we choose sampling points with high traffic level: the samples were collected in fields close to streets or roundabouts at three different distances, namely, 5 m (A samples), 10 m (B samples), and 15 m (C samples). The coordinates of each sampling point were measured by GPS. A further sample was collected in a nearby Natural Park ("Alpi Marittime" Natural Park, sample 13).

The plants were cut with a knife and stored in plastic bags.

They were subsequently washed with water. An aliquot of each sample was stored in plastic bags without any pretreatment and subsequently used for PAHs determination. The rest of the samples were dried at 70°C, ground in a mortar, and stored at room temperature.

Table 1: Site identification and description.

Number id code	Site	Municipal district	Coordinates
1	Roundabout	Marene	N44.39488° E7.44299°
2	Street	Genola	N44.35532° E7.39403°
3	Roundabout	Saluzzo	N44.38201° E7.30693°
4	Exit from motorway	Sant'Albano Stura	N44.28935° E7.41306°
5	Street near the railway	Fossano	N44.32112° E7.41604°
6	Roundabout	Fossano	N44.34129° E7.41570°
7	Roundabout	Cuneo	N44.69366° E8.01475°
8	Roundabout	Cherasco	N44.66714° E7.85439°
9	Roundabout	Bra	N44.66714° E7.86769°
10	Roundabout	Alba	N44.70400° E7.98449°
11	Roundabout	Bra	N44.66659° E7.80195°
12	Roundabout	Sanfrè	N44.759105° E7.79105°
13	"Alpi Marittime" Natural Park	Entracque	n.d.

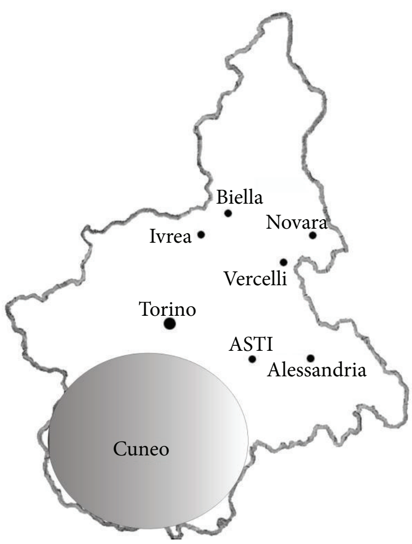

Figure 1: Map of Piedmont region showing the province of Cuneo, in which samples were collected.

An aliquot of soil was collected just at the bottom of each sampled plant. Only the first 5 cm of soil was collected in the area "around the roots." Soils were collected with a ladle and transferred to plastic bags. They were sieved through a 2 mm stainless steel sieve. One aliquot of the fraction with Ø < 2 mm was stored in plastic bags for the subsequent PAHs determination. The remaining aliquots were dried at 105°C and ground in a centrifugal ball mill in order to homogenise them.

2.2. Apparatus and Reagents. High-purity water (HPW) with a specific resistivity of 18 MΩ cm^{-1}, produced with a Millipore water purifier system, was used for the preparation of the samples and standard. All chemicals employed in this work were of analytical grade purity. Metal standard solutions were prepared from concentrated stock solutions (Merck Titrisol).

Sample dissolution was performed in polytetrafluoroethylene (PTFE) bombs, with a Milestone MLS-1200 Mega microwave laboratory unit.

Metal determinations were carried out with a Varian Liberty 100 inductively coupled plasma-optical emission spectrometer (ICP-OES) or with a Perkin Elmer Analyst 600 electrothermal atomic absorption spectrometer equipped with Zeeman-effect background spectrometer and graphite furnace (ET-AAS).

The determination of PAHs was carried out using a Varian Saturn 4D gas chromatography-mass spectrometer (GC-MS).

2.3. Procedure

2.3.1. Metals. For plant digestion, 500 mg of dandelion was transferred into the bombs and treated with 5 mL of HNO_3. Four heating steps of 5 min each (250, 400, 600, and 250 W power, resp.), followed by a ventilation step of 25 min, were applied.

For soil digestion, 100 mg of soil was transferred into the bombs and added with 5 mL of aqua regia. The same heating program as used for plants was adopted.

The resulting solutions were diluted to 50 mL with HPW and were directly employed for ICP-OES (Cr, Cu, Fe, Mn, and Zn) and GF-AAS (Cd, Pb) determination. External calibration was adopted using matrix matching of standards with the extracting mixture. Each sample was analyzed in duplicate. The following wavelengths were selected for the determination of elements using ICP-OES: λ_{Cr} = 267.716, λ_{Cu} = 324.754, λ_{Fe} = 259.939, λ_{Mn} = 257.61, and λ_{Zn} = 213.857 nm. For Cd and Pb determination, the analyses were made on 20 μL aliquots of sample solution added with 10 μL of matrix modifier (0.2 mg $(NH_4)_2HPO_4$ + 0.01 mg $Mg(NO_3)_2$ diluted to 10 mL of HPW).

Plant ability to take up chemical elements from growth media is evaluated with a parameter that can be called Biological Absorption Coefficient (BAC), index of bioaccumulation (IBA), Transfer Factors (TF), or biological accumulation factor (BAF) [29]. BAF refers to the ratio of heavy metals concentration in plant to that in soil; that is, BAF = C_p/C_s with C_p being concentration found in plant and C_s being concentration measured in soil [30]. Another parameter which can be used to understand the accumulation capability of heavy metals in plants is the metal accumulation index (MAI), calculated from the equation MAI = $(1/N)\sum_j^N Ij$, where N is the total number of metals determined and I is obtained for each metal dividing the mean concentration by its standard deviation. MAI is used as an important indicator for species selection in phytoextraction and urban greening [31].

2.3.2. Polycyclic Aromatic Hydrocarbons (PAHs). 30–40 g of fresh plant was transferred in a test tube with screw cap with Teflon seal. Then, an internal standard was added (2-bromonaphthalene) and three sequential extractions with acetone (20 + 20 + 10 mL) were made in an ultrasonic sonicator for 20 min each time, leaving the extract to equilibrate for 10 min before the next extraction. The obtained solutions were mixed together and diluted to 50 mL. 5 mL of the organic extract was then reduced to dryness under a gentle stream of N_2, and then 1 mL of dichloromethane as well as anhydrous sodium sulphate was added. The solution was analyzed by GC-MS.

For the determination in soils, 30–40 g of soil, dried at room temperature, was extracted in Soxhlet with 80 mL of acetone for eight hours. Before proceeding with the extraction 2-bromonaphthalene was added as internal standard. The organic phase was concentrated to 10 mL with the aid of a Rotovapor. Then it was reduced to dryness under a gentle stream of N_2 and after the addition of 1 mL of dichloromethane and anhydrous sodium sulphate the solution was analyzed by GC-MS.

2.3.3. Chemometric Data Processing. A chemometric analysis of the experimental results was performed by principal component analysis (PCA), with the aid of XLStat 7 software package, used as a Microsoft Excel plug-in. For the principles of the technique, the reader is referred to existing textbooks and papers on chemometrics (e.g., [32, 33]).

3. Results and Discussion

3.1. Metal Content

3.1.1. Plants. Table 2 reports the total content of the considered elements found in dandelion samples.

The results show that there is no regular trend of metal concentrations with distance, in contrast with the findings of other studies (see Section 1). This may be due to the fact that such studies regarded point sources of pollution and/or that the total distance from the street considered in our research (15 m) was too short.

In many samples Cr was present in concentrations lower than the instrumental detection limit. Fe and Mn content are homogeneous in all the samples, with few exceptions. Sample 3 generally contains the highest amount of elements.

Table 2: Metal concentrations (mg/kg) in *Taraxacum officinale* samples collected in traffic-impacted areas and in a National Park.

Sample	Cd	Cr	Cu	Fe	Mn	Pb	Zn
1A	0.18	12.6	7.84	1,623	142	1.83	28.8
1B	0.21	<0.4	9.16	72.6	57.0	0.23	24.3
1C	0.39	1.63	9.45	344	56.8	0.55	32.6
2A	0.23	<0.4	8.65	162	39.3	0.43	29.2
2B	0.23	<0.4	6.79	69.5	52.7	0.42	21.4
2C	0.24	<0.4	9.93	128	46.2	0.38	30.7
3A	0.24	1.54	21.8	427	61.8	0.45	66.1
3B	0.33	1.05	23.7	368	113	0.39	63.9
3C	0.25	16.4	28.8	2,632	170	2.27	68.2
4A	0.28	<0.4	13.5	261	43.2	0.58	53.0
4B	0.28	<0.4	7.61	138	46.1	0.38	26.0
4C	0.37	1.07	6.26	299	44.9	0.87	23.2
5A	0.13	<0.4	10.2	237	32.8	0.59	29.2
5B	0.21	<0.4	17.4	254	42.6	0.46	64.9
5C	0.17	<0.4	12.1	266	51.0	0.49	35.2
6A	0.19	<0.4	5.05	318	31.0	0.54	28.6
6B	0.20	<0.4	5.43	114	29.2	0.40	29.9
6C	0.18	<0.4	7.53	154	31.1	0.67	39.1
7A	0.09	0.63	7.96	154	31.8	0.72	49.7
7B	0.14	0.50	13.1	178	37.6	0.54	70.6
7C	0.11	6.05	8.88	620	51.2	1.04	38.2
8A	0.18	2.66	11.2	442	39.3	0.84	59.8
8B	0.15	4.21	11.5	621	50.4	0.79	35.4
8C	0.16	1.20	8.80	299	37.2	0.51	37.4
9A	0.19	2.94	18.2	462	42.6	1.03	66.1
9B	0.12	0.78	14.1	237	32.1	0.43	31.1
9C	0.11	1.59	12.7	253	37.6	0.54	43.2
10A	0.14	1.44	14.5	201	37.3	0.50	69.3
10B	0.20	1.76	12.9	338	43.5	0.54	36.6
10C	0.12	0.90	14.9	237	32.7	0.38	42.1
11A	0.13	0.59	17.0	261	44.1	0.43	62.7
11B	0.15	0.85	12.8	218	36.8	0.38	35.5
11C	0.10	0.87	10.3	254	42.6	0.39	27.4
12A	0.16	1.86	17.4	247	39.4	0.57	64.9
12B	0.12	2.38	11.4	361	42.3	0.46	28.8
12C	0.14	<0.4	10.4	355	34.7	0.45	33.3
13	0.13	1.41	14.7	153	23.3	0.54	45.1

In most of the sites, Zn is present in higher concentrations in the plants sampled 5 m far from the street, but also for this element a trend with the distance is not observed. Zn is released following car tires consumption [34], which can explain its higher concentration in A samples. For the same reason, we could expect this behavior also for Cu, but no significant differences among the different distance were observed for this element. We apply the test of the Analysis of Variance (ANOVA) to our data that shows that the differences in metal content found among 5, 10, and 15 m in each site are not significant, with the only exception of the Zn for which the concentration found in A distance

Table 3: Mean, median, and ranges of total concentrations (mg/kg) in *Taraxacum officinale* (samples 1–12) and reference values [14] for the average metal content in *Taraxacum officinale* leaves in rural "R" and industrial "I" areas.

Sample	Cd	Cr	Cu	Fe	Mn	Pb	Zn
Mean	0.19	2.85	12.2	378	50.1	0.62	42.4
Median	0.18	1.54	11.3	258	42.6	0.50	36.0
Range	0.09–0.39	<0.4–16.4	5.05–28.8	69.5–2,632	29.2–170	0.23–2.27	21.4–70.6
"R" range	0.3–1.0	0.2–2.4	5.2–20	70–644	14–206	0.8–6.4	21–84
"I" range	0.2–5.0	0.2–4.8	4.0–21.6	96–720	18–142	1.6–10	22–230

is significantly different if compared to the concentrations found in B and C.

The plants grown in the Natural Park present a low content in Mn, while the concentrations of the other elements fall in the ranges identified for the other samples.

Table 3 shows the mean, median, and ranges of the experimental results and typical reference ranges for *Taraxacum officinale* grown on rural ("R" ranges) and industrial ("I" ranges) soils found by Kabata-Pendias and Dudka. These values are commonly considered as baseline concentrations for the trace metals (Cd, Cr, Cu, Fe, Mn, Pb, and Zn) in dandelion grown in rural and industrial areas [14].

Comparing the results with the reference ranges, we can observe that the concentrations of Cd, Cu, Mn, Pb, and Zn fall in the "R" range or are even below it, with the only exception of sample 3, whose concentration is higher than the maximum level for the industrial sites. Three samples (1A, 3C, and 7C) present Cr content higher than the maximum of the "I" range and in two of these sites (1A, 3C) also Fe greatly exceeds this value.

Since dandelion is eaten like salad, we also compared the total metal contents with the maximum admissible concentrations in lettuce/wide leaf salad established by the World Health Organization (WHO) for Cd and Pb, namely, 0.2 and 0.3 mg/kg of fresh weight, respectively. The concentrations of Cd, calculated on the fresh leaves, do not exceed this level, while the content of Pb is higher than the maximum accepted value in two of the considered samples, namely, 1A (0.366 mg/kg) and 3C (0.454 mg/kg). These results suggest that caution should be used in consuming spontaneously growing vegetables. Anyway, it must be pointed out that this is a preliminary study, which should be extended to a larger number of samples, in a larger number of sites and at higher distance from streets. Presently, a risk associated with the consumption of dandelion growing in the investigated areas cannot be exactly quantified.

Table 4: Metal concentrations (mg/kg) in soil samples.

Sample	Cd	Cr	Cu	Fe	Mn	Pb	Zn
1A	0.15	77.5	18.9	26,821	717	23.8	82.4
1B	0.15	77.7	19.9	25,456	542	17.8	84.3
1C	0.13	71.0	23.1	24,914	527	16.8	85.7
2A	0.29	90.4	31.3	38,073	1063	27.7	131
2B	0.28	81.1	30.0	34,416	997	26.2	146
2C	0.28	83.7	31.6	36,384	1009	26.4	119
3A	0.12	126	38.5	33,043	772	19.1	110
3B	0.13	131	42.9	32,417	802	18.8	108
3C	0.14	105	23.7	31,603	741	17.1	96.4
4A	0.17	54.7	9.55	24,291	445	16.3	93.5
4B	0.14	58.3	10.0	24,744	475	17.2	66.2
4C	0.14	53.4	1.60	23,033	427	15.8	63.3
5A	0.23	72.5	20.4	18,101	547	27.7	89.9
5B	0.26	55.4	22.5	26,612	693	25.1	94.0
5C	0.23	49.4	8.59	25,751	660	22.9	91.8
6A	0.31	67.5	12.4	27,435	710	28.9	84.6
6B	0.34	69.6	22.8	29,762	915	26.0	87.7
6C	0.30	67.1	6.18	26,548	742	14.9	84.4
7A	0.13	76.5	19.9	13,485	269	35.2	80.4
7B	0.21	122	83.6	23,040	521	20.4	93.2
7C	0.20	64.1	27.7	17,917	471	16.7	81.9
8A	0.17	59.1	25.8	17,937	588	27.9	70.9
8B	0.25	78.1	70.7	21,066	516	21.3	95.5
8C	0.18	86.2	86.0	22,723	555	16.0	99.3
9A	0.21	76.0	39.8	15,848	366	18.0	90.5
9B	0.23	85.1	74.0	20,491	485	23.0	90.1
9C	0.21	56.6	16.1	16,702	440	19.3	68.5
10A	0.31	71.6	61.1	18,932	506	19.2	92.7
10B	0.33	79.3	80.5	21,141	470	19.6	100.6
10C	0.22	63.4	20.5	19,013	450	16.4	74.5
11A	0.22	81.6	57.2	20,745	492	24.8	93.4
11B	0.20	75.3	72.6	19,993	468	19.9	94.0
11C	0.16	59.8	22.8	17,572	458	15.2	59.3
12A	0.20	76.6	76.0	20,372	477	20.6	82.0
12B	0.19	67.0	32.6	12,987	271	94.2	142
12C	0.21	68.7	37.9	18,384	536	24.2	84.2
13	1.21	41.6	8.47	24,110	525	110	74.7

3.1.2. Soils. It is well known that soil is a major pathway for metal accumulation in plants: for this reason, we analyzed the soil underlying the dandelion samples. The total metal concentrations are reported in Table 4. The mean, median, and ranges are collected in Table 5, together with the maximum admissible levels of metals in soil according to the Italian Legislation [19] for the reclamation of contaminated sites. Italian limits depend on land use and are lower for public and private green areas and residential sites ("A" limits) and higher for industrial areas ("B" limits). In order to make a punctual distinction between anthropogenic and lithogenic fraction of metals for each soil, the collection of samples

Table 5: Mean, median, and ranges of total concentrations (mg/kg) in soils (samples 1–12) and reference values [19] for maximum allowable concentrations in soils in residential ("A" limit) and industrial ("B" limit) areas.

	Cd	Cr	Cu	Fe	Mn	Pb	Zn
Mean	0.21	76.1	35.5	23,070	587	23.3	92.0
Median	0.21	73.9	26.8	21,930	524	20.2	90.3
Range	0.12–0.34	49.4–131	1.60–86.0	2,300–38,070	269–1,070	14.9–94.2	59.3–14.6
"A" limit	2	150	120	—	—	100	150
"B" limit	800	800	600	—	—	1,000	1,500

along a depth profile would be necessary. In our case, we assessed the pollution level of the soils by comparison with such reference values and investigated whether a trend in concentrations, related to the distance from the street, was present.

The data show that the contents of Cd, Cr, Cu, Fe, Mn, Pb, and Zn are below the limits in all the investigated soils. These results confirm that the considered sites are rural areas not polluted by a particular point source of pollution. It can be observed that vehicular traffic did not cause a relevant increase of the metal concentrations in these soils. ANOVA treatment shows that the metal contents in soil sampled at A, B, and C distances are not significantly different in all the sites.

The concentration of Cu in the soil from the National Park is lower than the concentrations present in the other soils, whereas the concentration of Cd is higher but in any case below "A" limits. On the other hand, the high concentration of Pb, which exceeds such limit, may be due to the presence of galena (PbS), which is common in this area of Piedmont. Thus it can be presumed that Pb is naturally present in the soil and it is firmly bound to the crystalline structure, so it is not available for plant adsorption [35]. Fe and Mn contents in this sample fall in the range of the other sites.

Some studies demonstrated that, in the case of highly contaminated soils, it is possible to observe a good correlation between the concentrations in soil and in dandelion, in particular for Cd, Cr, Pb, and Zn [9, 13]. Such correlation was not observed in our study, probably because metal concentrations are present in relatively low amounts.

3.2. The Accumulation Capability of Plant. We calculated the ratio of heavy metals concentrations in aerial parts of wild plants to that in soil, which can reflect the uptake ability of plants to a single heavy metal. The BAF ranges obtained for Cd, Cr, Cu, Fe, Mn, Pb, and Zn were 0.45–3, n.d.-0.16 (where "n.d." stands for "not determined"), 0.10–3.91, $2{\cdot}10^{-3}$–0.08, 0.03–0.23, $5{\cdot}10^{-3}$–0.13, and 0.15–0.84, respectively. The BAFs obtained for plants sampled in the National Park fall in the range obtained for the other samples, with the only exception of Cd for which BAF value was lower (0.11). We can hypothesize that in the soils sampled in sites 1–12 Cd was present in a more available form, suggesting an anthropogenic contamination of the soil composition. Generally, BAFs values of elements like Fe and Mn are very low indicating that they are constituent of the mineral composition of the soil not easily adsorbed from the plants. In fact, even if Pb content in soil from National Park is very high, the corresponding BAF is very low ($5{\cdot}10^{-3}$) because this element takes part in the mineralogy of the soil.

According to the value of BAF calculated, the accumulation capability for dandelion is in the order Cd > Zn > Cu > Mn > Pb ≅ Fe ≅ Cr. This confirms the well-known capability of *Taraxacum officinale* to accumulate Cu, Zn, and in particular Cd present in the surrounding environment [13].

The order of bioavailability observed for these elements is quite common for vegetables. In particular, cadmium is assimilated by organisms because it has similar ionic structures, electronegativities, and chemical properties to zinc. However, Cd has stronger affinity for S than Zn, and thus its mobility in an acidic environment is higher. During weathering processes, Cd forms simple compounds such as CdO, $Cd(OH)_2$, $CdCl_2$, and CdF_2 that are easily mobile and behave like Zn, especially in sedimentation processes. For these reasons Cd is one of the most available metals for plants [36].

Kabata-Pendias and Pendias [29] discussed the index of bioaccumulation for spontaneous green plants. Their indices were approximately 10 for Cd, 1 for Zn, and 0.7 for Cu and Pb. Comparing these values with our results we observe that the BAFs obtained in our study are lower. This behavior is probably due to the low amounts of metals present in the considered soils.

Finally, we calculated MAI values. Generally this parameter is adopted to compare the capability of different species of plants to accumulate heavy metals. In this study MAI values were calculated for the same species sampled at different distances from a pollution source.

The MAIs obtained were 1.98, 2.25, and 1.61 for A, B, and C distance, respectively. Comparing these values with MAI obtained by Monfared et al. [31] for trees (*Platanus orientalis*: 2; *Robinia pseudoacacia*: 1.95; and *Fraxinus rotundifolia*: 2.22) studied for phytoremediation purposes, we can observe as *Taraxacum* presents higher value of MAI demonstrating the good capability of this plant to adsorb metals present in the surrounding area.

3.3. Chemometric Treatment. The chemometric treatment of the experimental data was carried out through the application of a well-known statistical multivariate analysis technique: principal component analysis (PCA).

The chemometric study was carried out on the total cation content in plants and soils separately and the combined plot of scores and loadings obtained is shown in Figures 2(a) and 2(b), respectively.

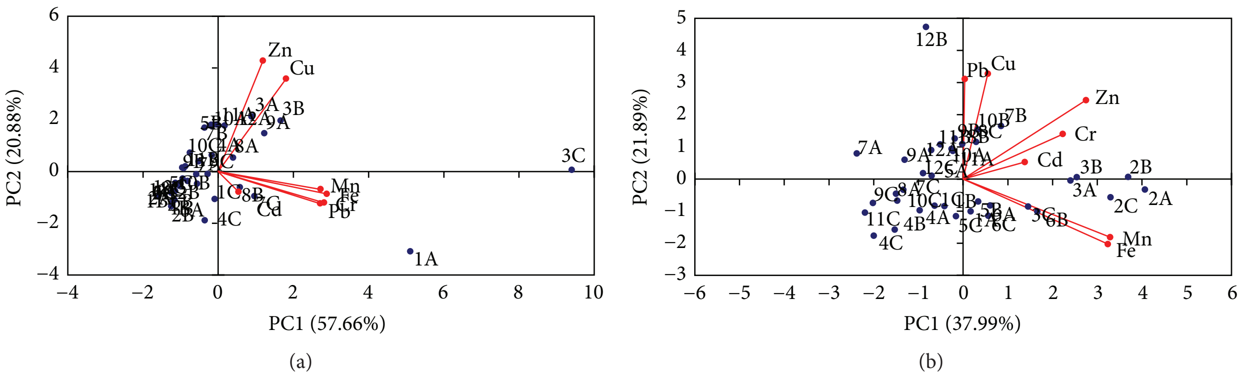

Figure 2: Combined plots of loadings and scores obtained by PCA.

Table 6: PAH concentration (μg/kg) in some dandelion (1A, 5A, 6A, 8A, 9A, and 11A) and soil (1A, 2A, 5A, 6A, 8A, 9A, and 12A) samples.

Sample	Naph	Ac	Ace	Flu	Phe	Anth	Fluo	Pery	Tet	Chr	∑
					Dandelion						
1A	<0.98	<1.05	<12.5	5.8	31.8	20.9	53.8	43.6	17.9	13.4	187.1
5A	<0.98	<1.05	<12.5	<3.28	4.4	<1.15	4.8	<4.80	<12.4	<3.44	9.2
6A	<0.98	<1.05	<12.5	<3.28	6.0	1.3	5.2	<4.80	<12.4	<3.44	12.5
8A	<0.98	<1.05	<12.5	<3.28	4.5	<1.15	4.5	<4.80	<12.4	<3.44	9.1
9A	<0.98	<1.05	<12.5	<3.28	<3.32	<1.15	5.0	<4.80	<12.4	<3.44	5.0
11A	<0.98	<1.05	<12.5	<3.28	3.7	<1.15	4.2	<4.80	<12.4	<3.44	7.9
					Soil						
1A	5.0	<1.05	16.7	9.4	34.8	4.2	12.6	11.7	12.2	6.8	113.4
2A	2.6	<1.05	15.3	8.9	35.2	4.4	16.1	15.4	<12.4	<3.44	97.9
5A	2.6	2.2	12.1	7.0	35.4	4.3	30.4	22.8	11.6	14.3	142.8
6A	<0.98	<1.05	11.6	<3.28	18.5	2.3	11.4	9.5	10.5	4.3	68.1
8A	10.1	<1.05	17.5	10.8	47.0	3.6	11.7	8.4	8.9	6.4	124.4
9A	9.5	1.7	12.9	7.1	25.4	2.6	9.2	9.3	9.2	7.1	94.0
12A	7.3	<1.05	14.0	7.8	30.5	2.6	9.5	8.4	8.5	3.7	92.4

∑ = sum of PAH concentrations in each sample.

The scores of the dandelions are in the same area of the biplot; in particular most of them are in the opposite plot region in comparison with the direction of the loadings; the only two exceptions are samples 1A and 3C, because these are generally characterized by the highest amount of considered metals. We can observe that F2 seems to influence A and B samples scores: this factor is probably related to the elements produced by the car tires consumption. In fact, Cu shows a good correlation with Zn ($r^2 = 0.765$) and they are load on F2. Regarding the other loadings, good correlation is observed among Cr and Fe and Mn and Pb and Si and these elements are load on F1.

Figure 2(b) shows the biplot obtained for soil samples: the scores are grouped in the opposite plot region in comparison with the direction of the loadings, with the exception of sample 2 (A, B, and C) and sample 3 (A, B, and C). As we can expect, Fe is well correlated with Mn ($r^2 = 0.915$), since their content depends on the amount of their oxides present in soils. Cu and Pb are load on F2, but no significant correlations are observed among the loadings. This behavior is probably due to the low metal content present in these rural sites and to the absence of point source of pollution.

3.4. PAHs Content. Table 6 reports the concentrations measured in some dandelion (1A, 5A, 6A, 8A, 9A, and 11A) and soil (1A, 2A, 5A, 6A, 8A, 9A, and 12A) samples. The most abundant PAHs found in all considered plants are phenanthrene and fluoranthene. These results confirm the data obtained by other researchers [37] who determined the PAHs concentration in grass sampled near motorways and airports. Sample 1A shows the highest concentrations of all considered PAHs and consequently the highest total content, equal to 187.1 μg/kg. This result is comparable with the total amount of PAHs found by Ducoulombier and Rychen in plants sampled near motorways (located in the northeast of France), namely, 188 μg/kg. These values are low if compared with other ranges reported in literature, from 1200 to 1461 μg/kg [38, 39]. PAHs content is strongly affected by several parameters: the sampling season (the concentrations increase 1 : 10 from summer to winter), vehicular traffic density, vehicle characteristics, climate, and type of the foliar surface.

Benz[a]anthracene and chrysene show detectable concentrations only in sample 1A, which suggests that these substances are easily leached by the rain and wind.

Also, in the soils, the most abundant PAHs are phenanthrene and fluoranthene. The soil that shows the highest total content of PAHs is 5A. In all the considered samples, the PAHs are present in concentrations lower than those obtained by other researchers ($\sum = 1292\,\mu$g/kg) in soils samples near motorways [37].

4. Conclusions

The comparisons between metal concentrations found in *Taraxacum officinale* grown in traffic-impacted areas and reference values suggest that vehicular traffic did not cause a relevant pollution of the plants, at least from the point of view of the investigated elements.

The lack of a significant trend in concentrations as a function of distance may be due to the relatively short distances considered.

Plants also accumulate metals from soils: in this case, the soils were not significantly polluted by the considered elements, and a correlation between plant and soil concentrations was not found. Such correlation is more frequently observed in the presence of contaminated soils.

The results for lead in the soil from the National Park indicate that high metal concentrations can derive from natural sources and not only from anthropogenic ones.

The obtained data confirm the good capability of dandelion to accumulate heavy metals, in particular Cd, Zn, and Cu.

The presence of concentrations higher than the maximum admissible levels of Pb in lettuce/wide leaf salad established by WHO indicates that caution should be used in consuming spontaneously growing vegetables.

It must be pointed out that this is a preliminary study, so the risk associated with the consumption of dandelion growing in the investigated areas cannot be exactly quantified: it can be presumed that such risk would be low, taking into account that dandelion is a seasonal plant, so its consumption is limited to a short period during the year, and that the concentrations were within the typical ranges for plants grown in rural soils. However, since *Taraxacum officinale* is known to be a hyperaccumulating plant, it is advisable to pick this plant up for consumption only in zones far from sources of metal pollution. In general, the collection and consumption of spontaneous vegetables must take into account the concept of food safety, which is the basis for the preservation of human health. Further studies involving also fruit and vegetables grown by farmers would be useful in deciding about the need to activate health monitoring campaigns by the regional authorities of public health.

Competing Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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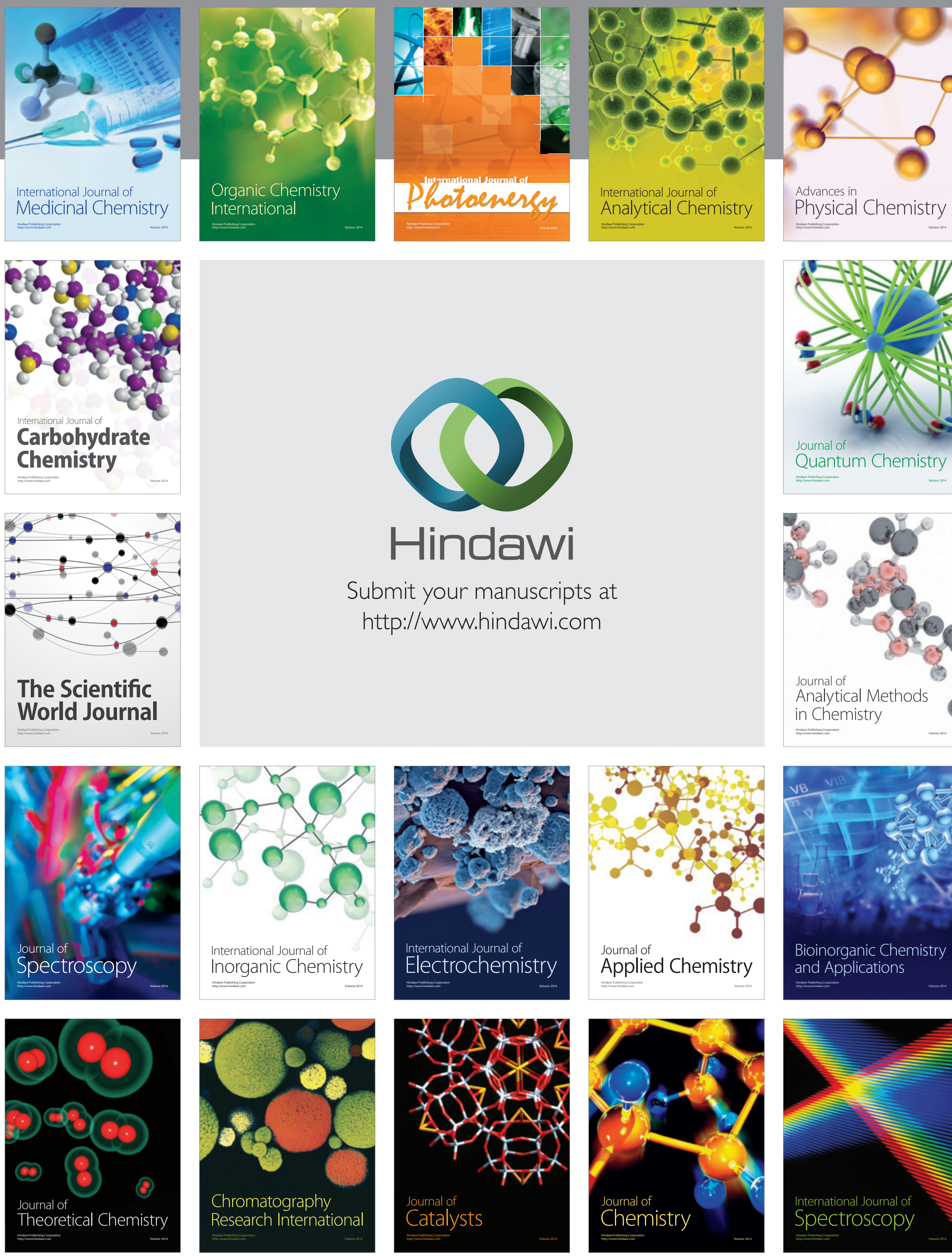
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