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Environmental & Socio-economic Studies

environ

DOI: 10.1515/environ-2015-0021

Environ. Socio.-econ. Stud., **2013, 1, 4: 29-40**

An assessment of urban habitat contamination with selected heavy metals within the city of Katowice using the common dandelion (*Taraxacum officinale* Web.) as a bioindicator

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ABSTRACT

The common dandelion (*Taraxacum officinale* Web.) is considered to be a good indicator species due to its wide spread and high tolerance to harsh environmental conditions. It was used in this study to assess contamination with selected heavy metals (Zn, Pb, Cd) within urban habitats of the city of Katowice (southern Poland). Samples were collected from outside the forest regions. Content of heavy metals was determined using Flame Atomic Absorption Spectroscopy (F-AAS). The soil mineralization was conducted using 50,0 cm^3 10% HNO_3. Determination of elemental concentrations in the plant material was carried out with the "wet" method using heating blocks for a period of 7-10 days. The following concentration ranges for individual elements in soil were found: 14,03–2049,50 mg kg^{-1} (Pb), 17,91–4118,00 mg kg^{-1} (Zn), 0,25–52,93 mg kg^{-1} (Cd). Concentrations within the leaves of common dandelion were: 5,52–93,04 µg g^{-1} (Pb), 71,71–807,15 µg g^{-1} (Zn), 0,10–15,69 µg g^{-1} (Cd). Plants from the most heavily contaminated soils were characterised by the lowest bioaccumulation coefficient. The most contaminated areas were the districts: Szopienice-Burowiec and Wełnowiec-Józefowiec, while the least contaminated were the southern districts of Katowice (i.e. Zarzecze, Podlesie). There is also a clear link between the content of heavy metals in soils examined in this study and the land use.

KEY WORDS: zinc, lead, cadmium, soil contamination, plant bioindicators

1. Introduction

Due to intense human activity, urban areas have quickly undergone significant transformations. Dense development, quick expansion of transport and industry have led to changes in all elements of the natural environment (disturbances of water regimes, transforming the terrain morphology, microclimatic changes) and increased levels of contamination. Extremely severe changes concerning all elements of the environment, and influencing living organisms, have occurred in the Upper Silesia Region for almost 200 years mostly due to mining activity and industrialisation.

Pollutants emitted into the atmosphere, including heavy metals, accumulate in the soil, from where they penetrate further trophic levels and directly affect living organisms, including algae, fungi and plants (DAVIES ET AL., 2003; JANKOWSKA ET AL., 2007; KALINOWSKA ET AL., 2008; SPODNIEWSKA ET AL., 2009). Within urban areas, plants play an essential role as a so-called filter that purifies the air from pollutants, and for humans they constitute an important line of defence against pollution caused by metal ions introduced into the environment from antrophogenic or geological processes. Some properties of plants, which allow for survival under conditions of contamination with metals, in soils, water or air, constitute a useful and easily accessible tool for environmental monitoring. The usefulness of the vascular plants to assess the state of the environment results from their continuous exposure to contaminants and difficulties with the changing habitat. The only way to survive within inhospitable area is by adaptation to stress associated with the presence of the toxic elements, a shortage of water or excessive salinity. Understanding the mechanisms for the transfer of metals and their concentration in roots, stems and leaves allows for an assessment of the impact of contamination and the degree to which they affect the surroundings. Living organisms are an important addition for the chemical methods of analysis of soil, water or air. The purpose of this urban environment monitoring was to determine the actual impact of anthropogenic pollution sources on the quality of life of the inhabitants. Parks, playgrounds, local squares, allotments and residential gardens, as well as agricultural areas neighbouring large urban centres should be listed among the areas which contamination may prove particularly dangerous for humans and animals, both wild and domesticated.

One of the basic methods of biological monitoring is to use bioindicators based on the observation of individuals or population reactions to particular factors (Świercz, 2004; Zimny, 2006). The observations may apply at various levels of organisation – from subcellular to landscape, such as changes in morphology, cellular structure, metabolic-biochemical processes, the degree of accumulation, the behaviour or the structure of a population (Markert, 2007; Świercz, 2004). All living organisms exhibit a specific sensitivity to pollutants and their reaction to stress constitutes the sum of the influence of numerous factors (Dećkowska, 2008; Szczepaniak & Biziuk, 2003).

In this study the ability to accumulate toxic elements was used. The main aim of this research was to evaluate the contamination levels of the soils in the city area of Katowice with selected heavy metals (lead, cadmium, zinc) and of the plant life within them, based on one of the more commonly occurring species in our climate zone – the common dandelion *Taraxacum officinale* Web. There was also an attempt to assess the usefulness of common dandelion as bioindicator species within urban habitats.

2. Materials, location and methods of research

2.1. Study area

The research was conducted within the city of Katowice (Upper Silesia, southern Poland). The area of the city comprises 164.5 km^2 and it is inhabited by 325 thousand people, thereby constituting the tenth biggest urban centre in the country (Raport ..., 2005). According to the *City Council Act of 29 September 1997* the area of the city has been divided into 22 districts (auxiliary units of the local government), assembled into 5 complexes (Uchwała..., 1997).

The city presents a full spectrum of land use types, from significant forest areas with nature reserves, through agricultural areas, loose single-family home developments, multi-storey residential communities, to the dense development of the downtown area, post-industrial barrens or the areas related to transport infrastructure (Wistuba & Waga, 2006). Due to this, three main types of landscape are visible within the city: urban-industrial, including the city centre (the northern and north-western parts), suburban-agricultural, where a share of the agricultural lands becomes significant in the south-western part, and the forest area landscape, formed by the complex of the Panewniki and Murcki Forests (Fojcik & Stebel, 2001). The city constitutes an important traffic junction in the region, through which run the main road and railway arteries, connecting Poland to Europe in all directions (Raport..., 2005). Mining activity is conducted within the city (Objaśnienia ..., 2004).

The leaves of common dandelion *T. officinale* Web., along with the soil samples, were collected between September and October 2008 from 67 collection points which were randomly chosen and distributed as regularly as possible within the administrative boundaries of the city of Katowice (Fig. 1). The material has been mainly collected from outside the forest regions, from within the areas of parks, squares and local open spaces, allotments, and barren vegetation areas. The samples from the region of the allotments were collected from outside of the cultivation areas in order to minimise the impact of the chemicals, fertilizers and procedures associated with it.

The leaves of *T. officinale* were collected from an area of approximately 1–5 m^2 from various individuals, in order to ensure the representativeness of the samples and to minimise the impact of inter-individual variability. The collected material was subsequently placed in paper bags, therefore protecting it against possible decomposition, occurring during a short time in plastic bags (Kabata-Pendias, 1998). The soil samples at each point were collected from three places located approximately 1–3 m away from each other from the surface layer of soil (0–10 cm), having previously removed the vegetation cover, and placed in fabric bags. All analyses were conducted in the laboratory of the Department of Ecology (Faculty of Biology and Environmental Protection, University of Silesia in Katowice).

2.2. Characteristics of the species

The common dandelion *Taraxacum officinale* Web. belongs to the aster family *Asteraceae.* It is a characteristic species for the grassland community of *Arrhenatheretalia* (Nawara, 2006), and is widespread in the temperate climate zone of Eurasia. It occurs commonly on pastures and ruderal habitats (PODBIELKOWSKI,1992; RUTKOWSKA, 1984; TYMARKIEWICZ, 1976). It exhibits a variability of leaf blade shapes depending on the habitat conditions (BALASOORIYA ET AL., 2009; MÜNKER, 1998; Steward-Wade et al., 2002). A significant feature that allows for its survival under hard conditions is its ability to reproduce asexually – the plant may regrow from cut roots due to the callus buds (TYMARKIEWICZ, 1976; MOWSZOWICZ, 1986). It is also characterized by a general tolerance to substances that act toxically, and has a high cumulating capability while lacking the sensitivity to cumulated substances. Despite the fact that the species is commonly considered as a weed, it tends to be cultivated in Western Europe and North America and used for culinary and herbalistic purposes (MOWSZOWICZ, 1983; NAWARA, 2006; PODBIELKOWSKI, 1992; SCHÜTZ ET AL., 2006; TYMARKIEWICZ, 1976).

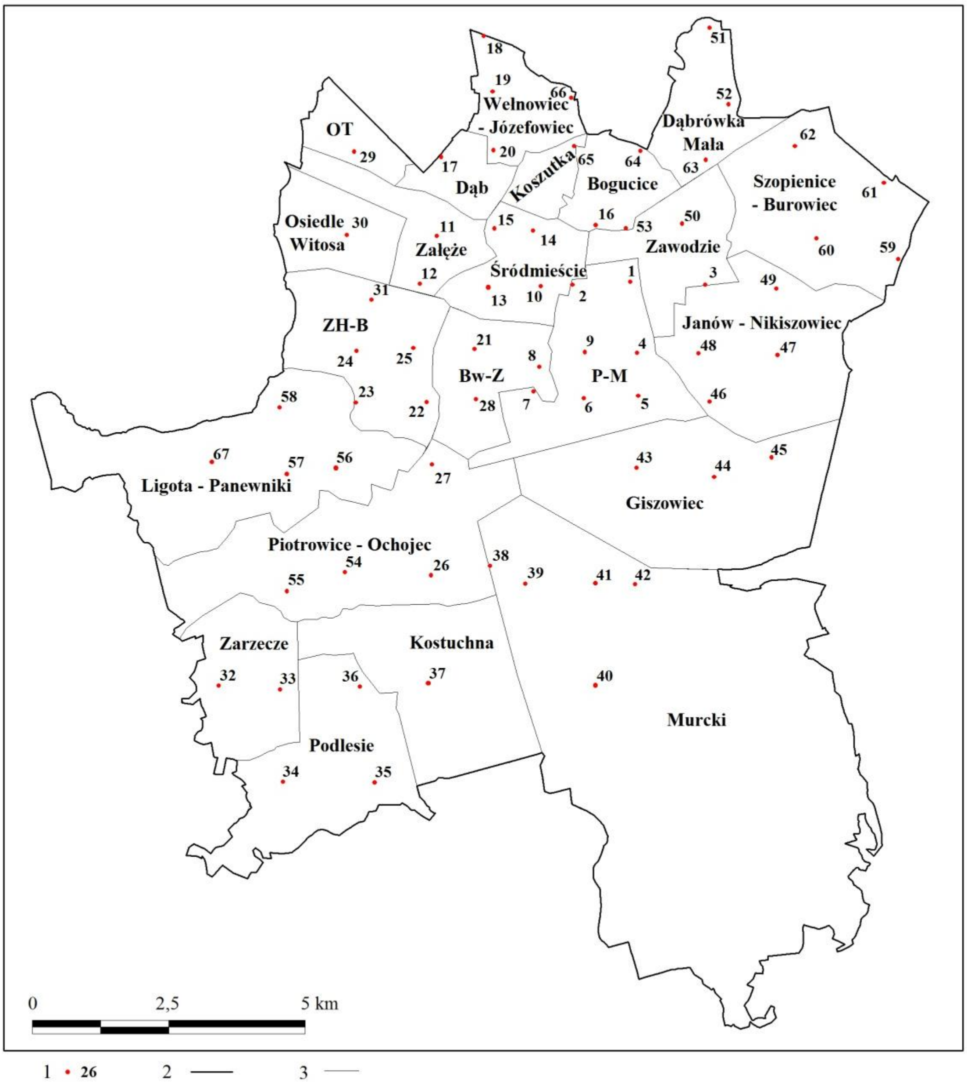

Fig. 1. Location of the collection points within the city of Katowice

1 – collection points; 2 – the city boundaries; 3 – boundaries of districts; OT – Osiedle Tysiąclecia; Bw-Z – Brynów – the eastern part – Osiedle Zgrzebnioka; ZH-B – Załęska Hałda-Brynów – the western part; P-M – Osiedle Paderewskiego-Muchowiec

This species has no high habitat requirements (NAWARA, 2006) and is resistant to drought (RUTKOWSKA, 1984), which makes it a good candidate to evaluate the degree of contamination within urban ecosystems, in which the water regimes undergo strong variations. In addition, it is a low lawn plant. This feature allows for achieving a more complete picture of the aerial contamination than an analysis of the composition of woody plants. It has also been confirmed that it accumulates more metals than the leaves of woody plant species, especially in the vicinity of transport routes, while remaining tolerant of air contaminants (KRÓLAK, 2003).

2.3. The research materials

The plant material was washed in running water in order to remove the dust pollution and larger particles present on the surface, and then rinsed using distilled water. The leaves were subsequently air-dried, subjected to the process of homogenisation and placed in clean paper bags. They were subsequently dried for 12 hours at a temperature of 105°C in the KBC-100 Thermal Test Chamber. In order to protect the material against mass changes caused by the absorption of humidity, the samples were placed in a desiccator. Aliquots were prepared from each sample with two replications.

The soil samples were dried in air, sieved through a sieve with a mesh size of 1.0 mm and mixed carefully. The more compact material was fragmented prior to sieving with a porcelain mortar and pestle. Reagent blank samples were also prepared for all the analyses.

2.4. Chemical research of the plant material

The so-called "wet" method implemented by BAYCU ET AL. (2006) was used to determine the content of heavy metals in the plant material. The leaves of *T. officinale* were ground and dried, aliquots (100-200 mg) were prepared in two repetitions. The mineralisation of the organic matter was completed using 4.0 cm^3 of concentrated nitric acid (65% HNO_3). The process was initially conducted at room temperature, and then on heating blocks at a temperature of 80–120°C, until a colourless solution resulted. The process lasted between 7 to 10 days. After the finished mineralisation the solution was filtered through hard filter paper. The Zn, Cd, Pb contents were determined using the Flame Atomic Absorption Spectroscopy method (F-AAS), using a mixture of air and acetylene as the carrier. Due to very low concentration of cadmium in plant material, determination of this element was performed using a graphite furnace (GF-AAS).

2.5. Chemical research of the soil material

50.0 cm^3 of a 10% solution of nitric acid (2N HNO_3) was added to conical flasks containing 5.0 g of air-dry soil each, the conical flasks were then shaken in a vortex mixer for one hour, in order to enable soluble compounds to penetrate the solution (OSTROWSKA ET AL., 1991). The solution was filtered through hard filter paper. The concentration of heavy metals was determined using the Flame Atomic Absorption Spectroscopy method (F-AAS), using a mixture of air and acetylene as the carrier.

3. Results

The mean values resulting from the plant material and soil analyses were presented graphically in the form of contamination distribution maps of the city area, prepared using Surfer 6.0 (Figs. 2A,B, 3A,B, 4A,B). For the samples collection sites, the type of the habitat was determined and the accumulation coefficient was calculated (Tab. 1).

The mean Pb content of the soil in the examined area equalled 180.7 mg kg^{-1}, the highest concentration (2050 mg kg^{-1}) was observed at point no. 59, located within the Szopienice-Burowiec district in the vicinity of the "Szopienice" Non-Ferrous Metal Smelter area. A similar situation occurred in the case of Zn and Cd. Their concentrations equalled 4118.0 mg kg^{-1} and 52.93 mg kg^{-1} respectively. The other point (no. 66) characterised by very high concentrations of heavy metals was located within the Wełnowiec-Józefowiec district next to the spoil tip of what used to be the „Silesia" Zinc Works. The least polluted soils were located within the southern districts: Zarzecze, Podlesie and Kostuchna, where the metal contents were low: Pb - approx. 14.0 mg kg^{-1}; Zn – approx. 18.0 mg kg^{-1}; Cd – approx. 0.25 mg kg^{-1}. Of all the examined metals, zinc was present in the highest amount. This is confirmed by the maps which show the distribution of the examined elements in the surface layer of the soil material (Figs. 2A, 3A, 4A). Similar to the soils, the highest accumulation of Pb, Zn and Cd was registered in the plant material originating from the north-eastern part of the city (Figs. 2B, 3B, 4B).

The average lead content in leaves of *T. officinale* equalled 27.3 μg g^{-1} of the dry matter. Relatively low accumulations of this metal in the leaves of *T. officinale* Web. were observed in the central part of the city in the Osiedle Padwerewskiego-Muchowiec district. At point no. 1 the concentration of Pb is as high as 5.5 μg g^{-1} of the dry matter. The plants which were most highly polluted with lead originated from the Szopienice-Burowiec, as well as Dąbrówka Mała districts.

The average zinc content of the leaves was 182.6 μg g^{-1} of the dry matter. The highest concentrations of Zn were recorded at point no. 66 in the Wełnowiec-Józefowiec district (approximately 807.0 μg g^{-1} of the dry matter), the lowest – approx. 72.0 μg g^{-1} of the dry matter – in Giszowiec at point no. 45. Similar values were obtained from the points 11 (Załęże) and 25 (Brynów).

Table 1. The accumulation coefficient in the leaves of *Taraxacum officinale* collected within the city of Katowice

Sample no.	Habitat type	The accumulation coefficient			Sample no.	Habitat type	The accumulation coefficient			Sample no.	Habitat type	The accumulation coefficient		
		Pb	Zn	Cd			Pb	Zn	Cd			Pb	Zn	Cd
1	Wasteland	0.038	4.890	4.154	24	Allotment	0.192	0.232	0.382	46	Lawn	0.400	0.217	0.641
2	Square	0.107	0.637	1.024	25	Lawn	0.587	0.499	0.759	47	Lawn	0.168	0.103	0.214
3	Wasteland	0.084	9.098	0.425	26	Wasteland	0.458	1.746	4.129	48	Lawn	0.056	0.381	0.207
4	Park	0.078	1.793	2.284	27	Lawn	0.141	0.104	0.326	49	Wasteland	0.500	0.751	0.935
5	Park	0.055	0.249	0.530	28	Wasteland	0.798	0.919	1.394	50	Lawn	0.097	0.122	0.226
6	Park	0.138	1.872	3.321	29	Lawn	0.270	0.154	0.315	51	Wasteland	0.562	0.113	0.685
7	Park	0.033	0.191	0.169	30	Lawn	0.564	0.528	1.048	52	Lawn	0.293	0.372	0.721
8	Allotment	0.157	0.445	0.433	31	Wasteland	0.284	0.361	1.317	53	Lawn	0.324	0.296	0.714
9	Lawn	0.181	0.046	0.795	32	Meadow	0.184	0.166	1.011	54	Lawn	0.154	0.414	0.134
10	Lawn	0.049	0.201	0.248	33	Meadow	1.768	1.632	8.088	55	Lawn	0.285	0.110	0.472
11	Lawn	0.077	0.167	0.533	34	Meadow	0.388	0.875	1.694	56	Lawn	0.335	2.336	2.722
12	Wasteland	0.022	0.101	0.094	35	Wasteland	0.975	1.273	2.108	57	Lawn	0.595	0.470	1.746
13	Square	0.101	0.217	0.493	36	Wasteland	0.686	0.913	4.391	58	Lawn	0.964	0.805	3.590
14	Square	0.127	0.321	0.586	37	Lawn	1.433	3.241	3.255	59	Wasteland	0.027	0.275	0.118
15	Lawn	0.070	0.197	0.180	38	Wasteland	0.187	0.620	3.203	60	Park	0.124	0.934	0.364
16	Roadside embankment	0.074	0.425	0.313	39	Wasteland	0.632	0.371	0.454	61	Lawn	0.258	1.480	0.590
17	Lawn	0.307	0.780	0.972	40	Wasteland	0.263	0.189	0.289	62	Wasteland	0.258	0.095	0.446
18	Wasteland	0.083	0.475	0.402	41	Lawn	0.410	0.139	0.376	63	Roadside embankment	0.451	0.219	0.618
19	Lawn	0.139	0.147	0.329	42	Wasteland	0.492	0.422	1.241	64	Allotment	0.130	0.486	0.361
20	Lawn	0.218	0.782	0.655	43	Wasteland	0.734	0.254	1.327	65	Lawn	0.198	0.471	0.550
21	Park	0.166	1.438	1.433	44	Park	0.264	0.102	1.808	66	Wasteland	0.100	0.817	0.233
22	Wasteland	0.393	0.480	0.659	45	Wasteland	0.787	0.078	0.965	67	Wasteland	0.445	0.314	1.949
23	Wasteland	0.252	1.271	0.579										

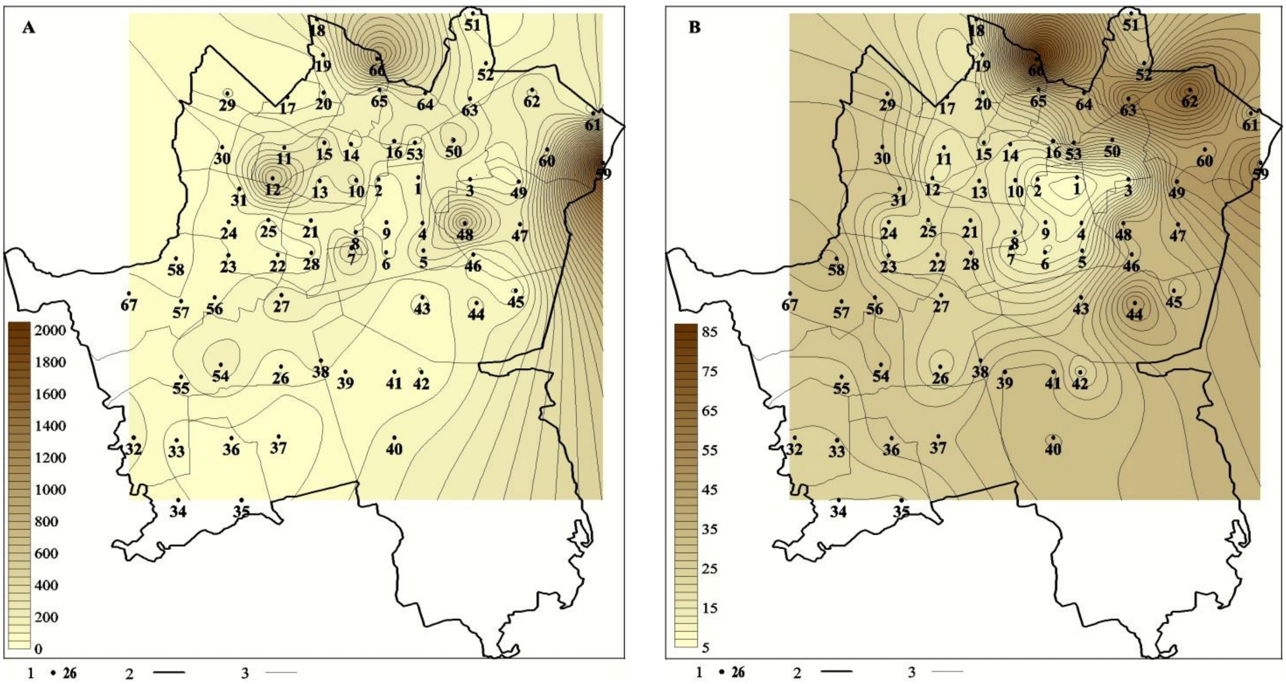

Fig. 2 A, B. Distribution of lead: A. in soil [mg kg^{-1}] and B. in *T. officinale* Web. leaves [µg g^{-1}] within the city of Katowice
1 – collection points; 2 – the city boundaries; 3 – boundaries of districts

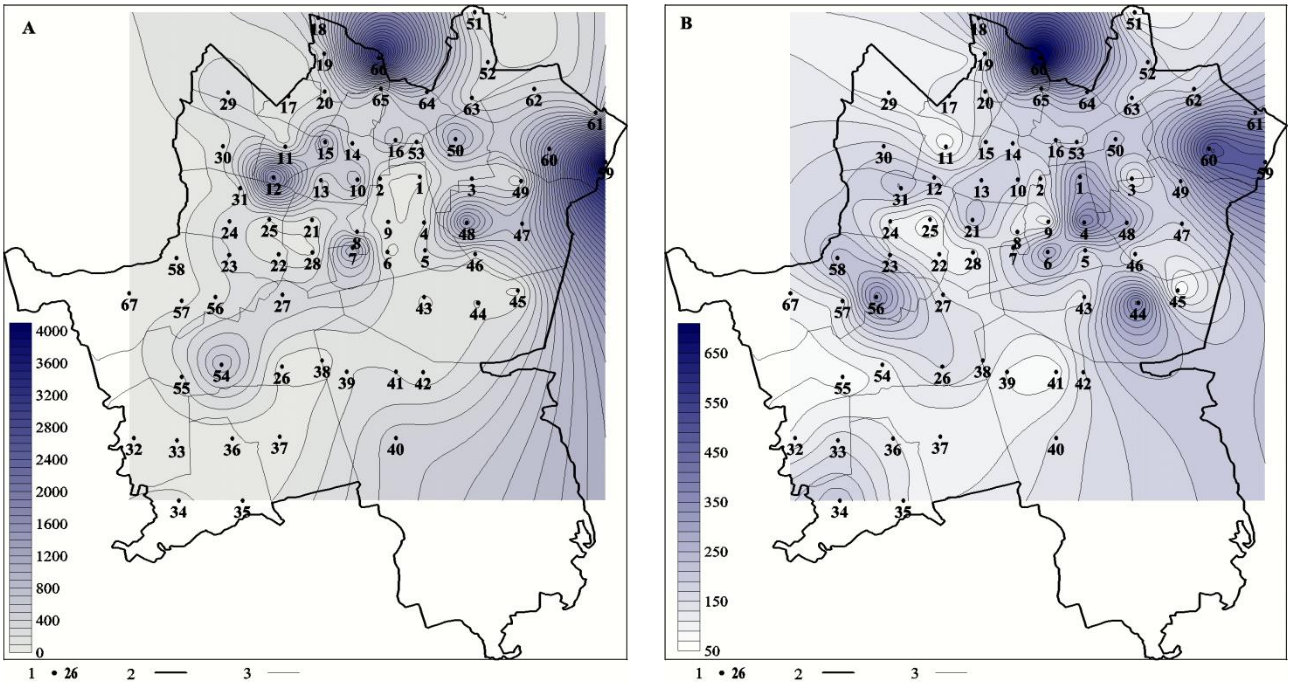

Fig. 3 A, B. Distribution of zinc: A. in soil [mg kg-1] and B. in *T. officinale* Web. leaves [μg g-1] within the city of Katowice. 1 – collection points; 2 – the city boundaries; 3 – boundaries of districts

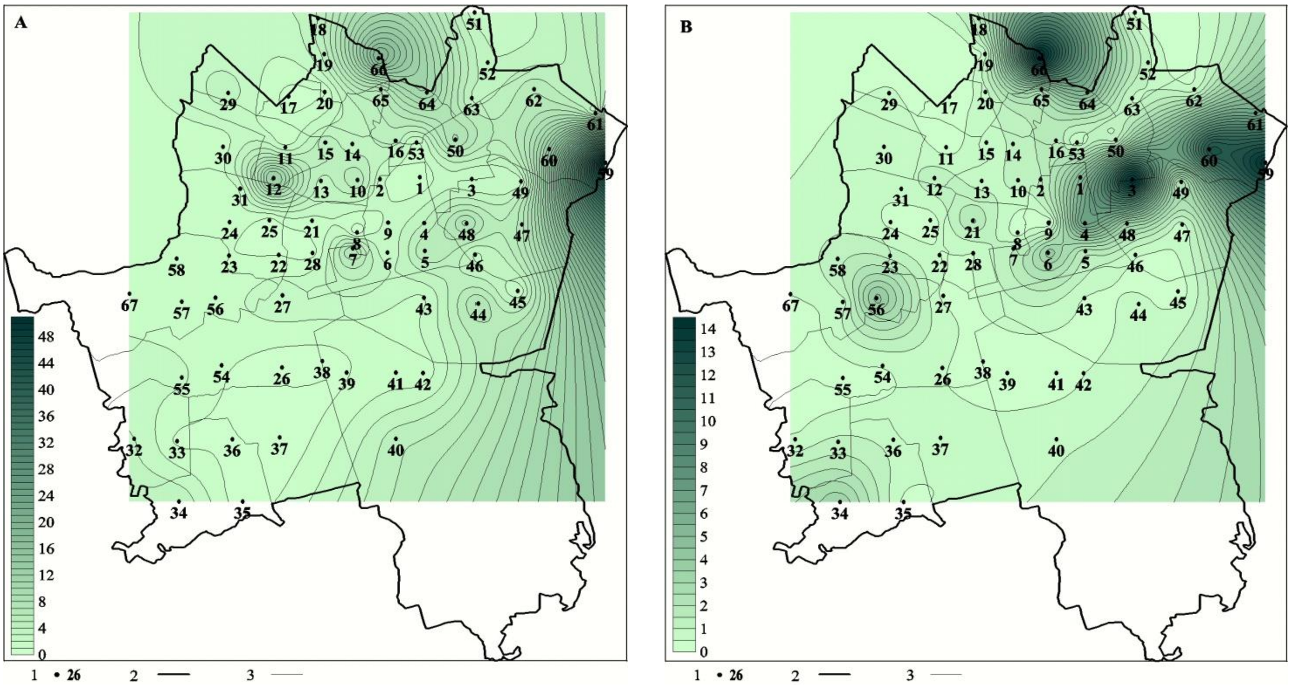

Fig. 4 A, B. Distribution of cadmium: A. in soil [mg kg-1] and B. in *T. officinale* Web. leaves [μg g-1] within the city of Katowice. 1 – collection points; 2 -the city boundaries; 3 – boundaries of districts

The mean cadmium content in leaves equalled 2.12 μg g^{-1} of the dry matter. As far as the distribution of Cd goes, three focal points of the occurrence of the highest concentrations are clearly distinguishable in the north-eastern part of the city. The leaves of *T. officinale* from the Osiedle Paderewskiego-Muchowiec district were the lowest in Cd (point no. 9; 0.10 μg g^{-1} of the dry matter). The highest concentrations were recorded at points 3 in the Zawodzie district and 66 - the Wenowiec-Józefowiec district (15.6 μg g^{-1} of the dry matter).

The accumulation coefficient of the individual metals has been presented in the table (Tab. 1), calculated as the ratio of an element content in leaves to its content in the soil. If the result of this quotient is larger than one it indicates a high degree of metal accumulation (DEĆKOWSKA ET AL., 2008). A high bioaccumulation of lead was observed only at two collection points, cadmium – at 12, and zinc – at 23. The highest record for zinc at point no. 33 was characterised by an accumulation coefficient higher than 8. At point no. 33 the high bioaccumulation level was also recorded in relation to other elements.

The correlations between the individual elements in the plant and soil samples were calculated using the Pearson correlation coefficient (Tab. 2).

The calculated correlation coefficients exhibited significant positive mutual correlations between the content of individual elements in the soil and between the heavy metals in the leaves of *T. officinale*. The high concentrations of Zn in the soil correlate with the high concentrations of Pb, Zn and Cd in the leaves. Positive correlations were observed between the elemental content of the soil and their transfer to the aboveground parts of the plant. Moreover, the Zn and Cd concentrations correlate in the dandelion leaves, confirming a direct geochemical relationship between these elements resulting from the presence of Cd in the mineral phases rich in Zn.

Table 2. Correlation coefficients (k) of heavy metals concentration in soil and leaves of *T. officinale*
*the level of significance p=0,05

		Soil			*T. officinale* leaves		
		Pb	Zn	Cd	Pb	Zn	Cd
Soil	Pb	x					
	Zn	0.94*	x				
	Cd	0.97*	0.91*	x			
T. officinale leaves	Pb	0.43*	0.50*	0.45*	x		
	Zn	0.60*	0.69*	0.61*	0.55*	x	
	Cd	0.33*	0.66*	0.62*	0.33*	0.76*	x

4. Discussion

Soils and plant life of cities whose historical and contemporary development is strongly associated with metalworking, chemical industry and mining, are highly subjected to the influence of synthetic and natural compounds rich in heavy metals, which can penetrate food chains.

The elements accumulate in organisms and their organs may be used to determine the stress caused by the impact of contaminants (PIERVITTORI & MAFFEI, 2001). Among the plant organisms that are used most frequently as bioindicators to assess the condition of the environment both by Polish and foreign researchers are the mosses (CHAKRABORTTY & PARATKAR, 2006; GAŁUSZKA, 2005; HARMENS ET AL., 2008; KALISZCZYK ET AL., 1997) and lichens (JÓŹWIAK, 2007; KŁOS, 2007; ŚLIWA, 2000; VAN HERK, 1999; WISEMAN & WADLEIGH, 2002). Also commonly used are the embryophytes (MADEJÓN ET AL., 2004; PIERVITTORI & MAFFEI, 2001; SANTAMARÍA & MARTÍN, 1997), including ruderal plants (DJINGOVA ET AL., 2004). Their usefulness for bioindication results mainly from their wide distribution, often high tolerance to toxic substances, the fact that many of them constitute the primary food of humans and livestock (DJINGOVA ET AL., 2004), and their quick reactions to the chemical changes of the environment (KRÓLAK, 2003). One example of such species is *T. officinale* examined in this paper, already used as an indicator of heavy metal contamination in local and supralocal research, for example in Poland (KRÓLAK, 2003), Germany (WINTER ET AL., 2000) or USA (KEANE ET AL., 2001). Due to its abundant occurrence both on the European and American continents (KEANE ET AL., 2001) it is useful for conducting research (including monitoring) regarding the urban habitats, which are relatively poor in species of lichens or bryophytes.

Within Katowice, the concentration of zinc in the common dandelion amounted to an average of 183.0 μg g^{-1}, ranging from 71.0 to over 800.0 μg g^{-1} of the dry matter. Considering that the concentrations of Zn in the range between 15.0 and 30.0 μg g^{-1} of the dry matter are sufficient to fulfil the physiological needs of most plants (KABATA-PENDIAS & PENDIAS, 1999) one may conclude that there have been no areas established within Katowice, within which the plants would be endangered with shortages of this element. Values ranging from 100 to 203 μg g^{-1} of the dry matter were recorded in leaves collected from the sites near the roads with high traffic intensity in Warsaw (CZARNOWSKA & MILEWSKA, 2000). KARCZEWSKA (2002) on the other hand has examined the concentration of zinc in the dandelion leaves within Wrocław, and these ranged from 35.0 to 1062.0 μg g^{-1} of the dry matter.

The average concentration of cadmium in the leaves of *T. officinale* collected from the area of Katowice is higher than the one quoted BY KABATA-PENDIAS & PENDIAS (1999) as occurring most frequently in the above ground parts (0.05–0.2 ppm). The leaves collected in the vicinity of landfills, former metalworks and mines (mainly within the Osiedle Paderewskiego-Muchowiec, Zawodzie, Szopienice-Burowiec and Wełnowiec-Józefowiec districts) have exhibited values ranging from 5.0 to 10.0 μg g^{-1} of the dry matter and above, which are considered phytotoxic for vulnerable plants. A concentration of 30.0 μg g^{-1} believed to be toxic for resistant plants was not exceeded in any case (KABATA-PENDIAS & PENDIAS, 1999).

According to the data quoted by DĄBKOWSKA-NASKRĘT ET AL. (2000) the Cd content in the above ground parts of *T. officinale* occurring in the area of Poland ranged between 0.2 and 5.0 μg g^{-1} of the dry matter. The majority of their samples were also within the same range – 83.5% as the ones collected from the Katowice area. The concentrations of cadmium in dandelion leaves examined in Warsaw ranged from 0.65 to 1.55 μg g^{-1} of the dry matter, with an average concentration of 0.97 μg g^{-1} of the dry matter, and the recorded values were independent of the distance from the road (CZARNOWSKA & MILEWSKA, 2000). The total concentrations of cadmium in the Kuyavian-Pomeranian voivodeship ranged between 0.95 and 4.98 μg g^{-1} of the dry matter (DĄBKOWSKA-NASKRĘT ET AL., 2000).

The mean concentration of Pb in the leaves of *T. officinale* from the Katowice area was higher than the one quoted by JANKOWSKA ET AL. (2007) as the natural lead content of the plants ranges from 1.0 to 1.5 μg g^{-1}. The natural content ranging from 1.0 to 5.0 μg g^{-1} of the dry matter assumed by NIESIOBĘDZKA (2005) was also exceeded in all the cases. KABATA-PENDIAS & PENDIAS (1999) claim that it is hard to determine the critical concentrations of lead for plants, however, they propose to assume 30.0–300.0 μg g^{-1} as such a range. The studies of common dandelion have not recorded any concentrations above 100.0 μg g^{-1} of the dry matter, and as many as 34% of the samples from Katowice fall within the proposed range. The concentrations ranging from 10.0 to 20.0 μg g^{-1} of the dry matter have been described by NIESIOBĘDZKA (2005) as being critical values for plant growth, and in the Katowice area only three samples have exhibited lower values. It is considered that the Pb content of the plants meant for consumption (e.g. as infusions) should not exceed 1.0 μg g^{-1} of the dry matter (JANKOWSKA ET AL., 2007; TRĄBA, 1998), and 10.0 μg g^{-1} of the dry matter in plants meant for fodder (TRĄBA, 1998). Juxtaposing those with the values resulting for common dandelion obtained from the area of Katowice, one can conclude that it must not be in any case used to prepare infusions.

Research conducted on soil and *T. officinale* leaves has shown a significant diversity in the heavy metal concentrations within the city of Katowice. For the highest concentrations of Pb, Zn and Cd a clear, direct relationship with the land use methods has been observed (e.g. vicinity of metalworks and landfills and agricultural areas).

The knowledge of the distribution of contaminants allows for an assessment of the health risk to the inhabitants. This assessment is most frequently based on the existing law standards valid in particular countries. However, the permitted concentrations do not always reflect the actual dangers regarding the health of humans and animals and also to plant life. In the ones currently used there is no information regarding the capability of leaching out particular metals into soil solutions from the natural or synthetic mineral phases in which they are present in the soil. So far there have been no uniform standards of the acceptable concentrations of harmful substances accepted in the world, either for agricultural or for urban areas. The individual countries approve the range limits adjusted to the local geological and climatic conditions and the land use method (PASIECZNA, 2003), which often span significantly (Tab. 3). Adjusting the acceptable values, which vary depending on the purpose and land use method, allows for adequate utilisation of the area and minimises the health effects of heavy metal impacts. LOMBI ET AL. (1998) have presented a German example, and when the given values were exceeded it indicated the need to monitor a given area, in order to change the way the land was utilised or rehabilitated.

The acceptable concentrations for areas of Poland are defined in *The Resolution of the Minister of Environment of 9 September 2002 regarding the soil quality standards and the earth quality standards* (ROZPORZĄDZENIE…, 2002), in which three soil groups have been distinguished and the acceptable concentrations have been defined for each of them (Tab. 3).

Table 3. Acceptable values of Zn, Pb i Cd [mg kg^{-1}] in soil (Cabała, 2009)

Metal	Germany (a)	Netherlands (b)		Poland (c)			Poland (d)		
	L	MV	IV	A	B	C	0	II	IV
Zn	200	430	720	100	300	1000	50-100	300-1000	3000-8000
Pb	150	308	530	50	100	600	30-70	100-500	2500-7000
Cd	1.5	6.4	12	1	4	15	0.3-1	2-5	5-20

(a) – Bundes-Bodenschutzgesetz – BbodSchG, 1998; Altlastenverordnung – BbodSchV, 1999; L – clayey soil, (b) Netherlands Ministry of Housing Dept. of Soil Protection (625) Spatial Planning and Environment 1994; MV – the average value for intervention, IV – the maximum acceptable value, (c) – Dz.U. 165p.1359, 2002; A – natural protected areas, B – croplands, forest- and built-up lands, C – industrial- and communication areas, fossil lands (the values for the top layers of soil), (d) – Kabata-Pendias et al., 1995; 0, I, II, III, IV, >IV – contamination levels; 0 – natural background, II – slightly contaminated, IV – heavily contaminated

The acceptable concentrations for areas of Poland are defined in *The Resolution of the Minister of Environment of 9 September 2002 regarding the soil quality standards and the earth quality standards* (Rozporządzenie ..., 2002), in which three soil groups have been distinguished and the acceptable concentrations have been defined for each of them (Tab. 3).

For protected areas the acceptable standards for Pb, Zn and Cd were not exceeded except in soils collected from several points within the southern and western districts. This research has proved that the collection sites located near the protected areas of Katowice are characterised by heavy metal contents exceeding the above mentioned acceptable concentrations. The most heavily stressed is in the vicinity of the "Las Murckowski" Nature Reserve (among other things, due to the close proximity of the landfill at Bielska St.) and the Szopienice-Borki Nature-Landscape Complex. Ciepał (1999) has examined the heavy metal contents within the selected protected areas of the Silesian voivodeship, including the "Las Murckowski" Nature Reserve in Katowice. He obtained a similar cadmium content (5.0 mg kg^{-1}) of the surface soil level, along with the concentrations of zinc (150.0 mg kg^{-1}) and lead (90.0 mg kg^{-1}). The increased concentrations in the collection sites located in the proximity of the protected areas indicate their potential risk.

The acceptable values of metal concentrations in the upper soil layers for the areas of industry, transport and mining (group C; Rozporządzenie..., 2002) were exceeded for lead in 22.4% of the collected samples, for zinc in 8.9% of the samples, and the concentrations of cadmium exceeded the acceptable standards in 2 samples, originating from the areas next to the metalworks waste disposal sites in Szopienice and Wełnowiec. The metal concentrations in the remaining collection sites fall within the range set for the second group – B (Rozporządzenie ..., 2002).

The results obtained from the park and square areas near the local neighbourhoods are similar to those obtained from the areas of the neighbouring cities (Siemianowice, Dąbrowa Górnicza, Ruda Śląska, Sosnowiec, Bytom), in which the samples were collected from recreational areas, parks and playgrounds (Nieć et al., 2013).

Research conducted within the Katowice area revealed high significant positive correlations between the metal content of the soil and the plants have been exhibited for all the examined heavy metals (Tab. 2). In the case of cadmium and zinc those were high correlations, however, for lead the correlation was mediocre. This means that in the case of this research the dandelion reacted quantitatively for the concentration of metals in soil and it may serve to assess the pollution within the city. On the other hand the research of Dąbkowska-Naskręt et al. (2000) conducted in the Kuyavian-Pomeranian region did not exhibit a statistically significant correlation between the cadmium content of the dandelion leaves and of the soil. Zeidler (2005) determined a positive correlation, over twice as weak as the case of Katowice (0.29), between the zinc content of the leaves and the concentration in the soil in the protected landscape area in the Czech Republic, in which area heavy metals may originate from the neighbouring sewage plant, the flow of polluted air from the industrialised areas and chemical fertilisers. Significant correlations in the Zn and Cd contents in leaves and soil were also determined by Winter et al. (2000).

The crucial factor in assessing the extent of the plant stress caused by heavy metals is knowledge about the background levels, obtained from research of the exact chemical composition of the plants and determination of the natural ranges of the content of the individual elements – the so-called "fingerprinting of plants" (DJINGOVA ET AL., 2004). Table 4 presents the content ranges for the examined elements in the leaves of *T. officinale* considered to be natural and characteristic for the regions of Europe and the United States, including Cd, Zn and Pb. The values resulting for Katowice in most cases exceed the given ranges, which indicate a significant enrichment of plants by heavy metals. The ranges established by the author were not exceeded for cadmium in the case of 49% of the samples, three collection sites, on the other hand, were characterised by contents which were lower than the one proposed. The concentrations of lead exceeded the background values in virtually all the cases, which prove the high enrichment of plants in this metal, probably due to atmospheric deposition, which is indicated by the calculated low accumulation coefficient of this metal from the soil. In 13 samples the zinc content fell within the range that is considered to constitute a natural concentration.

The highest average accumulation coefficient in leaves of *T. officinale* in the Katowice area was 1.18 for zinc. A value of 1.22 was obtained by ZEIDLER (2005) when examining the Litovelské Pomoraví Protected Landscape area. KARCZEWSKA (2002), when examining the zinc content in the Wrocław area noticed that the accumulation coefficient of zinc ranged from 0.12 to 1.07. She also proved that under conditions of high Zn content of the soil its absorption by the common dandelion was also high, and its content regarding both the roots and the leaves was well correlated with the total zinc content in the soils. KARCZEWSKA (2002) noticed the lowest bioaccumulation coefficients for the plants from the most heavily polluted soils, and this was also confirmed during this research in the Katowice area. Similar conclusions were reached by KOWOL ET AL. (2000) while examining the roots of the dandelion from southern Poland with regard to their cadmium content when comparing the results obtained from the industrial and recreational areas. This research has resulted in a low value of the accumulation coefficient of Cd in the industrial areas, which may, however, be misleading compared to the coefficient for the samples originating from the less polluted areas. This results from the proportional growth of the cadmium content of the dandelion roots in the industrial areas compared with the content of the soil for that metal, and its disproportionately higher accumulation in the roots in recreational areas (KOWOL ET AL., 2000). ZIEDLER (2005) achieved the highest accumulation coefficient for cadmium, which was the most highly absorbed element (Cd>Pb>Zn). Zinc was the most heavily accumulated element in Katowice, while the absorption gradient presented itself differently: Zn>Cd>Pb.

High significant positive correlations were demonstrated in the leaves of *T. officinale* collected in the Katowice area between lead and zinc content, zinc and cadmium content, along with a mediocre correlation for lead and cadmium. In the leaves of common dandelion collected at various distances from the Warsaw roads (CZARNOWSKA & MILEWSKA, 2000) significant correlations were observed between lead and zinc (0.457), cadmium and zinc (0.600) as well as cadmium and lead (0.558). KEANE ET AL. (2001) have observed a high positive correlation only in the leaves between lead and zinc (0.581).

Table 4. Range of heavy metal concentrations in the leaves of *T. officinale* proposed by different authors as background values (Djingova i in., 2004; Królak, 2004)
A – Djingova et al., 2004; B – Królak, 2004 (after: Kabata-Pendias, Dudka, 1991); C – Królak, 2004 (after: Rule, 1994)

	Cd	Zn	Pb
	[μg g^{-1}]		
A	0.2–0.8	30–100	0.3–6
B	0.3–1.0	20–110	1.6–6.5
C	0.6–0.8	44–78	0.8–3.1

5. Summary and conclusions

The studies conducted within the city of Katowice showed that soils coming from the northern part of the city were heavily contaminated with Zn, Cd and Pb. The districts which were most heavily polluted with these heavy metals include Szopienice-Burowiec and Wełnowiec. This results from the presence of industrial waste disposal sites within them which still affect the nearby surroundings. Soils with the lowest levels of contamination were recorded within the southern districts, where the agricultural landscape is significant. Only a few samples met the requirements designated in Poland for protected areas. This suggests that such areas should be subjected to particular care leading at least to maintenance of the actual levels of pollution.

Analyzing the results one can notice a clear link between the content of heavy metals in soils examined in this study and the land use. The highest concentrations appeared within industrial areas and fallow lands. Among the least contaminated places were the agricultural areas, squares and lawns near housing estates and parks. Within the area of the city centre (Śródmieście district and neighbouring areas), characterised by compact and dense building and a lack of green space, the contamination levels were generally at an intermediate level.

An analogous situation was noticed in the plant material. Leaves of *T. officinale* originating from industrialized areas exhibit highest concentrations of heavy metals. Plants obtained from southern, agricultural areas were much less loaded with the examined metals. Nevertheless, the common dandelion from any of the collection points must not be used to prepare infusions. *T. officinale* leaves were marked by a Pb content higher than values considered as natural background which suggests its noticeable enrichment, probably due to atmospheric deposition. Elements were absorbed according to the following gradient: Zn>Cd>Pb. Research also showed that plants from the most heavily contaminated soils were generally characterised by the lowest bioaccumulation coefficient. Moreover, the high bioaccumulation of the elements e.g. at point 33, where low concentrations of the examined elements were observed, indicates that the dandelion is capable of absorbing significant amounts of heavy metals present in the soil environment. Moreover, it reacts quantitatively to metal concentration, which makes it useful in assessing the pollution in different areas of the city.

Biological monitoring not only serves to examine the condition of the environment, but also provides information about the metal concentrations in the plants which should constitute an important indicator regarding the capability of the soils to leach out metals from the solid phases present into the forms of ionic, metal organic or chelate compounds, from which the heavy metals are easily accessible for the plants. This information may be useful for the assessment of the possible threat to the health and life of humans and other organisms living within the examined area.

To understand the metal transfer mechanisms associated with *T. officinale* it is necessary to conduct further chemical, biochemical and microscopic analysis, to allow the recognition of the deposition sites and metal concentrations in the above ground and below ground plant organs.

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