POLISH JOURNAL OF SOIL SCIENCE
VOL. L/1 2017 PL ISSN 0079-2985

DOI: 10.17951/pjss/2017.50.1.41

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BIOACCUMULATION OF HEAVY METALS IN HERBAL PLANTS FROM AREAS NOT EXPOSED TO HEAVY ANTHROPOPRESSURE

Received: 28.05.2017
Accepted: 04.07.2017

Abstract. The aim of the study was to evaluate the content of Zn, Cu, Mn, Pb, Hg and Fe in sandy everlasting, yarrow and stinging nettle in relation to the concentration of metals in the soil. Samples of soils and plants were collected from natural habitats (edges of forests in the Kujawy-Pomerania Province). The total metal content and their available forms for plants in the soil samples were determined. The stinging nettle inhabited the richest environmental areas in which anthropogenic accumulation of metals in the surface of soils was determined. The investigated soils were not contaminated with heavy metals and the content of their plant-available forms was not harmful for a proper plants growth. The content of metals extracted with the diethylenetriaminepentaacetic acid was considerably higher than the concentration referred to as the deficit level for plants. Among the analyzed herbal plants, sandy everlasting contained the largest amounts of copper, manganese, and only concentration of lead in dry weight was higher than 10 mg·kg^{-1}, indicating that the plants harvested from the study areas should not be used in herbal medicine. Bioconcentration factor (BCF) values point clearly to the mercury and zinc accumulation in the aboveground parts of herbal plants.

Keywords: trace elements, enrichment factor, bioaccumulation, herbaceous plants

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Heavy metals are natural constituents of the soils but human activities have altered their geochemical cycles and bioavailability because heavy metals are no-biodegradable contaminants, which may be absorbed into the tissues of plants (Peralta-Videa *et al.* 2009, Tóth *et al.* 2016). Harmfulness of trace elements first of all related to their ability to bioaccumulation, which involves the increase of these elements within plant tissues (Kabata-Pendias and Krakowiak 1997, Luo *et al.* 2012). Herbaceous plants are rich sources of minerals, vitamins, and also have beneficial antioxidative effects but intake of heavy metal-contaminated herbs may pose a risk to the human health. In the case of herbaceous plants which particular morphological parts are collected for therapeutic destination, the place of trace elements' accumulation is extremely important. Exposure to mentioned above elements may cause the mineral composition changes within the plant organs and also the synthesis inhibition of biological active substances in plant tissues which finally effects the therapeutic value decrease of plant raw material applied in phytotherapy (Kuźniewski *et al.* 1993). Herbal plants can be used as a bioindicator of environmental changes for that reason that they are sensitive to unfavourable soil conditions, especially in reference to heavy metal pollution. The trace elements detected in soil only reflect information about the sampling location, but the metals uptake by plants gives information about their accumulative effects (Kabata-Pendias 2004). Additionally, it also supplies the information about the phytotoxicity of trace elements to plants.

Poland belongs to the biggest exporters of herbal plants in Europe. These plants are collected from both monitored arable plantations and natural sites. The world health organization recommends that herbal plants, which form the plant-based medicines, should be checked for the presence of heavy metals. However, majority of these plants are harvested without checking for heavy metal accumulation.

The aim of this study was the assessment of Zn, Cu, Mn, Pb, Hg and Fe content in plants utilized in phytotherapy in relation to heavy metal contents and their bioavailability in the soils from areas not exposed to heavy anthropopressure.

MATERIALS AND METHODS

In the experiment, the total content of Zn, Cu, Mn, Pb, Hg and Fe in the soil and roots and over-ground parts of the sandy everlasting (*Helichrysum arenarium* (L.) Moench), yarrow (*Achillea millefolium* L.) as well as stinging nettle (*Urtica dioica* L.), were evaluated. The plant material was collected from places adjacent to the forest communities in the Kujawy-Pomerania Province. While choosing the collection points it was important to collect representative samples in relation to the basic soil parameters. Samples of soil and plants were collected in triplicate near the village: **A** – Łochowo (53°07′19″N; 17°50′19″E), **B** – Kruszyn Krajeński (53°04′53″N; 17°51′52″E), **C** – Łosiny (53°37′13″N; 17°58′43″E).

Soil sampling was undertaken in the summer of 2015. The rhizospheric soil adhering to root surface (0–20 cm) of the herbal plants was also collected after gently shaking the plant roots. Plant samples were also collected at the same time. Furthermore, some soil samples were also undertaken from a depth of 120–150 cm to estimate the metal content of the local geochemical background. Soil samples were air dried and crushed and then passed through 2 mm sieve for physical and chemical analysis. Soil pH was measured using glass electrode in 1 mol dm^{-3} KCl solution (1:2.5 soil-solution ratio). Soil total organic carbon (TOC) was determined by TOC analyzer vario Max CN Elementar Analysensysteme GmbH (Hanau, Germany). Soil texture was measured by Mastersizer 2000 (Malvern Instrument, Malvern, the UK). Above-ground parts of plants were gently separated (stems, leaves and flowers) from roots. Total metal contents were determined by digestion with HF and $HClO_4$ solutions, according to the Crock, Severson (1980) method. Certified reference materials (TILL-3, the Canadian Certified Reference Materials) were used to check the accuracy of the results. Recovery rates for the analyzed elements were as follows: 97%, 101%, 101%, 102%, 99% and 103%, for Zn, Cu, Pb, Mn, Fe and Hg, respectively. The content of available metal forms in soils were determined by using 0.005 mol L^{-1} diethylene triamine pentaacetic acid (DTPA), 0.01 mol L^{-1} $CaCl_2$, and 0.1 mol L^{-1} triethanolamine (TEA). Thirty millilitres of DTPA solution (pH=7.3) were added to soil samples (15 g) in polypropylene bottles, which were shaken for 2 hours and then centrifuged for 10 min at 3,000 rpm. Plant samples were washed thoroughly by deionized water, and then dried at 50°C for 48 hours. After that, plants were ground to powder for metal analysis. About 0.3 g plant sample was digested with a 5 ml 65% HNO_3, 1 ml 30% H_2O_2 mixture in the microwave digester Speedwave Two (Berghof). Heavy metals (Zn, Cu, Mn, Pb, Fe) were determined for both the above-ground parts and roots of the plant by the atomic absorption spectrometer. Applying the atomic absorption spectrometry method (AAS), using spectrometer Philips PU 9100 X (Cambridge, the UK), there was determined the concentration of metals in soil samples and plant materials. The total content of mercury was determined by atomic absorption spectrometry using the AMA-254 analyzer.

Pearson's correlation analysis was also done between the soil properties and total content of metals variables. The statistical analyses were made using Statistica 10.0 (StatSoft Inc, Tulsa, the USA). The values of the indicators such as contamination factor (*CF*), enrichment factor (*EF*) allow to evaluate the potential ecological risk of the contamination with trace elements. The value of *CF* was calculated by the following formula:

$$CF = C_m / C_{mb}$$

where: CF – the contamination factor; C_m – the content of metal in topsoil; C_{mb} – the background concentration of metal. For the calculations it was assumed that the content of metals at the depth of 120–150 cm corresponds to the content of the local geochemical background. The following terminologies were used to describe the degree of contamination categories: low<1; moderate $1 \leq CF < 3$; considerable $3 \leq CF < 6$, very high ≥ 6.

The human activity impact on soils was estimated by using enrichment factor (*EF*). The values of the enrichment factor (*EF*) were calculated according to the formula:

$$EF = [C_n/C_{nFe}]/[B_n/B_{nFe}]$$

where: C_n – total content of metal; C_{nFe} – total content of Fe as the reference element; B_n – content of metal for the geochemical background; B_{nFe} – content of Fe for geochemical background (Martin and Meybeck 1979). Based on value of *EF* the enrichment categories were determined as: <2 – deficiently to minimal enrichment, 2–5 – moderate; 5–20 – considerable; 20–40 very high; >40 – extremely high enrichment (Sutherland *et al.* 2000). Trace elements accumulation is described by the value of bioconcentration factor (*BCF*); organs of plant-to-soil metal concentration ratio. The values of the bioconcentration factor (*BCF*) were calculated according to the formula:

$$BCFa = CM_a/CM_s$$
$$BCFr = CM_r/CM_s$$

where: CM_a – content of metal in above-ground parts (flowers, stems, leaves); CM_r – content of metal in roots; CM_s – total content of metals in soil. The values of the translocation factor in plants (*TF*) were also calculated:

$$TF = CM_a/CM_r.$$

RESULTS

Most of the studied soil samples had loamy sand texture and only one sample of sandy everlasting rhizospheric soil had particle size composition of sand with content of fractions: sand – 86.49%; silt – 11.90% and clay fraction – 1.61%. The highest pH value (7.03) was measured for C sampling points in which the mean total organic carbon content was the lowest (24.6 $g \cdot kg^{-1}$) (Table 1). Total contents of metals in soil surface horizon were varied and ranged for Zn from 22.6 to 190 $mg \cdot kg^{-1}$; Cu from 4.1 to 17.8 $mg \cdot kg^{-1}$; Mn from 298 to 574 $mg \cdot kg^{-1}$; Pb from 9.5 to 29.5 $mg \cdot kg^{-1}$; Hg from 11.4 to 83.5 $\mu g \cdot kg^{-1}$ and Fe from 7.8 to 17.3 $g \cdot kg^{-1}$ (Table 2–4). Parent material of analyzed soils in sampling locations contained: zinc from 22.4 to 39.4 $mg \cdot kg^{-1}$; cooper from 4.2 to 6.3 $mg \cdot kg^{-1}$;

TABLE 1. PROPERTIES OF SOIL SAMPLES

Place sampling	Content of particle size fractions (%) Sand (mm) ϕ 2.0-0.05	Silt (mm) ϕ 0.05-0.002	Clay (mm) ϕ <0.002	pH	C_{org} g·kg^{-1}
A (n=3)					
Min.	77.42	17.90	1.58	5.19	19.8
Max.	80.72	20.64	2.23	7.11	45.0
Mean	78.65	19.48	1.73	6.18	29.3
SD	1.80	1.42	0.44	0.96	13.67
CV [%]	2.3	7.3	25.5	15.6	46.7
B (n=3)					
Min.	75.54	11.90	1.61	5.51	13.0
Max.	86.49	22.71	2.77	7.08	44.1
Mean	80.38	17.57	2.04	6.21	26.1
SD	5.58	5.42	0.63	0.80	16.13
CV [%]	7.0	30.9	30.9	12.9	61.8
C (n=3)					
Min.	79.23	17.64	1.41	6.36	16.8
Max.	80.12	18.47	3.03	7.38	30.1
Mean	79.53	18.19	2.24	7.03	24.6
SD	0.51	0.47	0.81	0.58	6.94
CV [%]	0.7	2.6	36.2	8.3	28.3

manganese from 384 to 498 mg·kg^{-1}; lead from 10.2 to 19.2 mg·kg^{-1}; mercury from 10.1 to 31.1 μg·kg^{-1} as well as iron from 8.6 to 18.2 g·kg^{-1}. In rhizospheric soil sampled from stinging nettle locations, it was recorded the highest total content of metals. Value of enrichment factor (*EF*) amounted respectively for: Zn from 2.3 to 6.1; Cu from 1.9 to 3.0; Mn from 1.0 to 1.2; Pb from 1.4 to 1.7; Hg from 2.4 to 3.3, pointing to anthropogenic accumulation these metals in soil surface horizon. At the localities of stinging nettle, it was determined the highest percentage share of available metals forms for plants in total content (Table 5). Content of Cu_{DTPA} comprised the highest percentage share in Cu total content, especially in C sampling points from 15.7% to 29.1% (Fig. 1). However, the percentage share of available form of iron in total Fe content was the lowest in all sampling locations and ranged from 0.3% to 4.7%. Comparing the mean metal content of studied herbal plants it was concluded that: most of Zn was found in the above-ground parts of sandy everlasting (69.2 mg·kg^{-1}), the least in the roots of yarrow (18.6 mg·kg^{-1}); the most Cu in the above-ground parts of sandy everlasting (10.9 mg·kg^{-1}), the least in the roots of stinging nettle (1.63 mg·kg^{-1}): the most Mn in the above-ground parts of sandy everlasting (204 mg·kg^{-1}), the least in the roots of yarrow (17.7 mg·kg^{-1}); the most Pb in the roots of sandy everlasting (29.5 mg·kg^{-1}), the least in the above-ground parts of yarrow (4.30 mg·kg^{-1}); the most Hg in the above-ground parts of sandy everlasting (52.9 g·kg^{-1}), the least in the roots of yarrow (7.07 μg·kg^{-1}) and the most Fe in the roots of stinging nettle (671 mg·kg^{-1}), the least in the roots of sandy everlasting (84.8 mg·kg^{-1}) (Table 2–4).

TABLE 2. TOTAL CONTENT OF Fe (g·kg^{-1}), Zn, Cu, Mn, Pb (mg·kg^{-1}), Hg (µg·kg^{-1}) IN RHIZOSPHERIC SOILS AND CONTENT OF Zn, Cu, Mn, Pb, Fe (mg·kg^{-1} d.w.), Hg (µg·kg^{-1} d.w.) IN DRY WEIGHT OF SANDY EVERLASTING (*HELICHRYSUM ARENARIUM* L.MOENCH)

Place sampling	Metals	Rhizospheric soil	Parent material	Sandy everlasting		*TF*	*CF*	*EF*
				Above-ground	Roots			
A	Zn	25.8	22.4	44.6	29.5	1.5	1.1	1.2
B		22.6	26.5	69.2	58.1	1.2	0.8	1.0
C		29.0	27.4	34.7	35.4	1.0	1.1	1.1
A	Cu	5.2	4.6	10.9	12.4	0.9	1.1	1.2
B		4.1	4.2	8.26	5.00	1.6	1.0	1.2
C		5.5	5.9	8.28	6.03	1.4	0.9	1.0
A	Mn	325	384	167	170	1.0	0.8	0.9
B		354	421	204	154	1.3	0.8	1.0
C		298	408	28.7	30.5	0.9	0.7	0.7
A	Pb	11.2	10.6	11.8	21.4	0.5	1.1	1.1
B		9.5	10.2	11.8	25.3	0.5	0.9	1.1
C		12.1	12.7	17.0	29.5	0.6	0.9	1.0
A	Hg	18.9	14.7	37.2	30.6	1.2	1.3	1.4
B		19.7	16.9	52.9	44.9	1.2	1.2	1.4
C		22.1	20.1	8.90	11.4	0.9	1.1	1.1
A	Fe	9.8	10.4	259	84.8	3.0	0.9	–
B		7.8	9.4	260	660	0.4	0.8	–
C		8.4	8.6	259	307	0.8	1.0	–

TF – translocation factor, *CF* – contamination factor, *EF* – enrichment factor

TABLE 3. TOTAL CONTENT OF Fe (g·kg^{-1}), Zn, Cu, Mn, Pb (mg·kg^{-1}), Hg (µg·kg^{-1}) IN RHIZOSPHERIC SOILS AND CONTENT OF Zn, Cu, Mn, Pb, Fe (mg·kg^{-1} d.w.), Hg (µg·kg^{-1} d.w.) IN DRY WEIGHT OF YARROW (*ACHILLEA MILLEFOLIUM* L.)

Place sampling	Metals	Rhizospheric soil	Parent material	Yarrow		*TF*	*CF*	*EF*
				Above-ground	Roots			
A	Zn	38.4	28.1	45.5	34.3	1.3	1.4	1.3
B		31.4	27.9	60.6	19.1	3.2	1.1	1.1
C		49.9	30.6	56.1	18.6	3.0	1.6	1.5
A	Cu	7.8	5.1	6.08	2.03	3.0	1.5	1.5
B		7.4	5.0	3.68	2.20	1.7	1.5	1.4
C		6.5	6.1	4.67	1.73	2.7	1.1	1.0

Place sampling	Metals	Rhizospheric soil	Parent material	Yarrow		*TF*	*CF*	*EF*
				Above-ground	Roots			
A	Mn	385	411	130	113	1.1	0.9	0.9
B		323	401	50.8	27.2	1.9	0.8	0.8
C		417	498	30.8	17.7	1.7	0.8	0.8
A	Pb	15.0	15.2	5.41	7.57	0.7	1.0	1.0
B		14.2	14.0	5.60	7.03	0.8	1.0	1.0
C		17.1	17.1	4.30	7.37	0.6	1.0	0.9
A	Hg	23.3	20.2	21.5	11.2	1.9	1.1	1.1
B		12.4	10.1	26.1	7.67	3.4	1.2	1.2
C		11.4	10.2	21.7	7.07	3.1	1.1	1.0
A	Fe	12.3	11.9	282	187	1.5	1.0	–
B		11.4	11.2	333	143	2.3	1.0	–
C		12.9	12.0	364	96.2	3.8	1.1	–

TF – translocation factor, *CF* – contamination factor, *EF* – enrichment factor

The highest values of bioaccumulation factors (Fig. 2–4) within above-ground parts and roots of studied plants were noted for sandy everlasting, whereas the lowest values of *BCF* factor were achived for stinging nettle although these plants were collected from the soil sampling areas characterised by the highest metal content. Both total metals content as well their available forms for plants from all sampling points were concerned. At the sites from which stinging nettle was collected it was also noted the highest values of distribution factor and metal enrichment factor which amounted respectively: *CF* from 0.9 to 5.8 and *EF* from 1.0 to 6.1. The higest values of these factors were calculated for zinc. A strong positive correlation was observed between the content of organic matter and the total content of Cu, Pb, Hg and between the content of available form of Cu, Mn and Fe (Table 6). The interactions between analyzed metals were also noted.

TABLE 4. TOTAL CONTENT OF Fe (g·kg^{-1}), Zn, Cu, Mn, Pb (mg·kg^{-1}), Hg (μg·kg^{-1}) IN RHIZOSPHERIC SOILS AND CONTENT OF Zn, Cu, Mn, Pb, Fe (mg·kg^{-1} d.w.), Hg (μg·kg^{-1} d.w.) IN DRY WEIGHT OF STINGING NETTLE (*URTICA DIOICA* L.)

Place sampling	Metals	Rhizospheric soil	Parent material	Stinging nettle		TF	*CF*	*EF*
				Above-ground	Roots			
A	Zn	99.1	39.4	48.7	25.4	1.9	2.5	2.3
B		190	38.6	45.5	37.8	1.2	4.9	5.2
C		176	30.1	36.8	65.1	0.6	5.8	6.1
A	Cu	16.6	5.6	2.68	2.23	1.2	3.0	2.9
B		17.8	6.2	2.18	1.63	1.3	2.9	3.0
C		11.5	6.3	2.43	2.33	1.0	1.8	1.9

Place sampling	Metals	Rhizospheric soil	Parent material	Stinging nettle		TF	*CF*	*EF*
				Above-ground	Roots			
A	Mn	451	447	76.6	87.3	0.9	1.0	1.0
B		574	484	56.1	36.1	1.5	1.2	1.2
C		436	429	71.3	42.0	1.7	1.0	1.1
A	Pb	27.2	19.2	7.08	7.30	1.0	1.4	1.4
B		29.5	18.7	6.52	4.87	1.3	1.6	1.7
C		21.7	16.6	6.22	4.57	1.4	1.3	1.4
A	Hg	54.0	22.3	49.4	34.3	1.4	2.4	2.4
B		83.5	26.4	37.1	27.6	1.3	3.2	3.3
C		71.6	31.1	23.4	8.07	2.9	2.3	2.4
A	Fe	15.2	15.0	338	207	1.6	1.0	-
B		17.3	18.2	322	153	2.1	0.9	-
C		17.1	17.8	506	671	0.7	1.0	-

TF – translocation factor, *CF* – contamination factor, *EF* – enrichment factor

TABLE 5. CONTENT OF DTPA EXTRACTABLE Zn, Cu, Mn, Fe IN RHIZOSPHERIC SOIL ($mg\cdot kg^{-1}$)

Metals		Sandy everlasting	Yarrow	Stinging nettle
Zn_{DTPA}				
	A	1.6	3.7	6.7
	B	1.5	1.7	33.6
	C	3.8	1.6	28.9
Cu_{DTPA}				
	A	0.6	0.6	0.6
	B	1.3	0.4	0.6
	C	1.6	1.8	1.8
Mn_{DTPA}				
	A	11.3	16.8	68.1
	B	8.3	6.2	14.0
	C	4.1	4.2	7.4
Fe_{DTPA}				
	A	60.2	167	431
	B	77.3	46.5	818
	C	54.9	39.1	157

TABLE 6. CORRELATION COEFFICIENTS

Elements	C_{org}	Fe	Hg	Pb	Mn	Cu
Zn	0.62	0.91*	0.97*	0.86*	0.86*	0.84*
Cu	0.81*	0.87*	0.87*	0.98*	0.87*	
Mn	0.62	0.86*	0.83*	0.90*		
Pb	0.76*	0.92*	0.86*			
Hg	0.76*	0.83*				

Elements	C_{org}	Fe	Hg	Pb	Mn	Cu
Fe	0.51					
Zn_{DTPA}	0.53					
Cu_{DTPA}	0.70*					
Mn_{DTPA}	0.68*					
Fe_{DTPA}	0.79*					

*Significant correlation coefficient at $p<0.05$ (n=9)

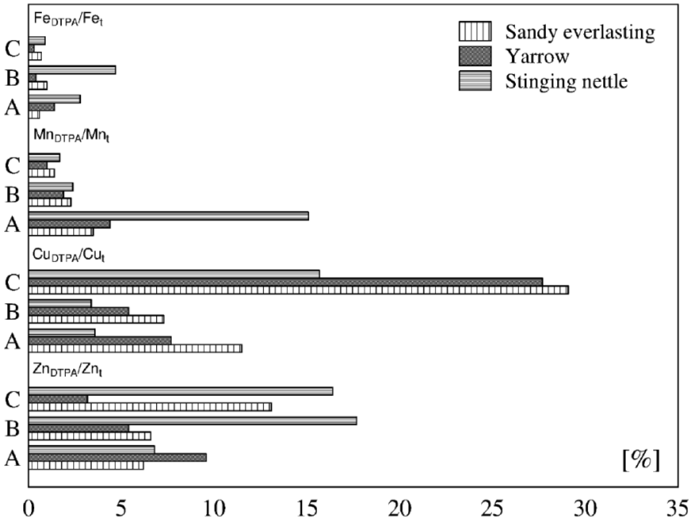

Fig. 1. Percentage share of DTPA forms in total content of metals

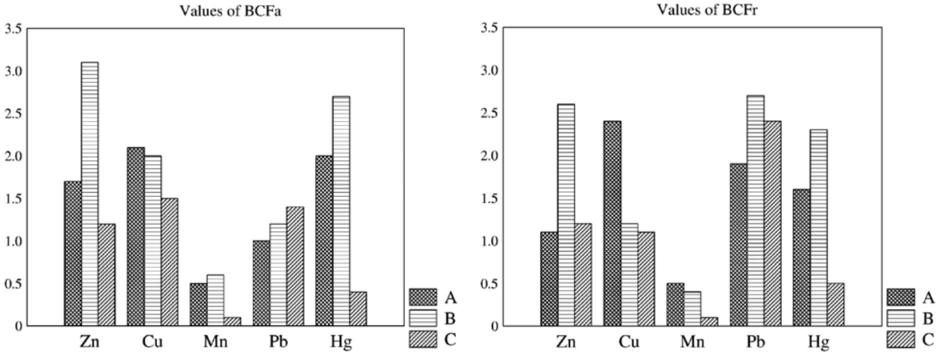

Fig. 2. Bioacumulation factor in sandy everlasting

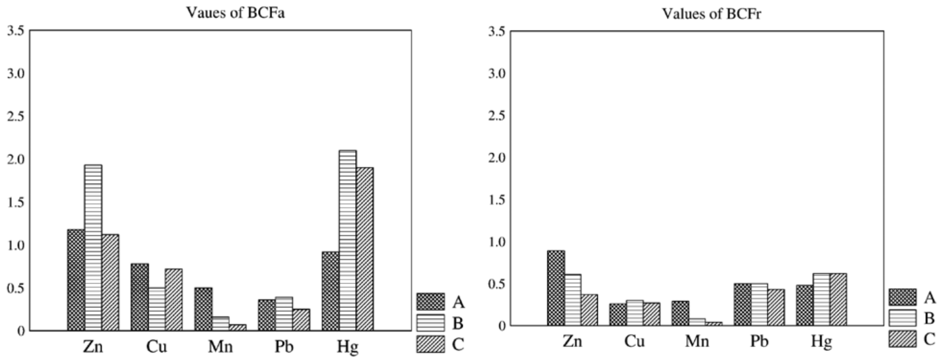

Fig. 3. Bioacumulation factor in yarrow

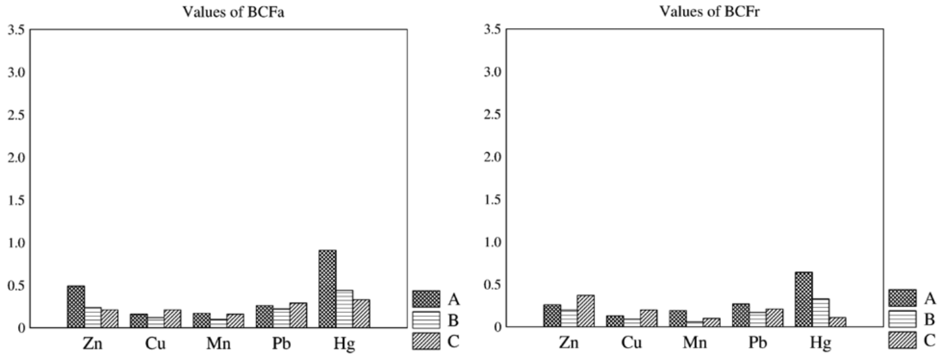

Fig. 4. Bioacumulation factor in stinging nettle

DISCUSSION

Studied soils were not polluted by heavy metals (Journal of Laws No 165, item 1359, 2002**)** and their content in parent material was typical for soils (North of Poland) developed from Baltic glacial sediments (Kobierski and Dąbkowska-Naskręt 2012). From the study, the concentrations of metals were different in the same plants collected from different sampling locations.

An accurate risk assessment must be performed by accounting not only total concentrations of heavy metals in soil but also their actual mobility (Remon *et al.* 2005). Using method with DTPA we observed that the mobile fractions were largely element-dependent (from mean 15.1% of total content for Cu to mean 1.4% for Fe). Thus, it can be assumed that metals present in soil from our sampling places were poorly phytoavailable. Similar percentage of metals DTPA-extractable in their total content were observed in soils in Szubin Forest Management area (Kujawy-Pomerania Province) (Kobierski *et al.* 2011). The content of metals extracted with the DTPA solution in the analyzed soil samples was considerably higher than the concentration referred to as the deficit level for plants (Lindsay and Norvell 1978). Trace metals from analyzed soils were poorly leachable but their transfer to aboveground part of plants cannot be ruled out. Moreover, it is well known that some of plants can modify metal solubility (Ge *et al.* 2000), especially through exudates release and/or modification of soil microbial activity and/or as a results of micorrhizae (Hildebrandt *et al.* 2007, Regvar *et al*. 2006, Rajkumar *et al.* 2012).

The mercury bioconcentration factor (*BCF*) and translocation factor (*TF*) values point to an accumulation in the above-ground part of herbal plants. In the analyzed soils the geochemical background content of mercury is relatively low. The areas do not undergo an excessive anthropopressure and sources of Hg depositions in soil surfaces can be the deposition of mercury from air. Probably the main source of mercury in above-ground part of analyzed herbal plants was the atmosphere. Researchers reported that the main source of mercury in leaves of plants is the atmosphere (Fay and Gustin 2007, Kowalski and Frankowski 2016, Windham-Myers *et al.* 2014). The analyzed herbal plants can be used as biomarkers of the environmental risk of pollutants, because they are able to uptake (Bontidean *et al.* 2004). However, the bioaccumulation factor (*BCF*) referred to available Hg in soils was lower for stinging nettle where the content of mercury in the rhizospheric soils was the highest. Both the value of *BCF* and the translocation factor (*TF*) can positively affect phytoextraction. Plants with high value of *BCF* and low *TF* (lower than 1) have potential for phytostabilisation (Yoon *et al.* 2006). The lowest *TF* values were noted for lead which points that metal is not transported into above-ground parts of plants but it is accumulated in roots. It concerns sandy everlasting and yarrow. The above-ground parts and roots of sandy everlasting accumulated considerable amount of lead, despite of the fact that content of that metal in the rhizospheric soil was relatively low. Values of contamination factor and enrichment factor indicated to slight accumulation of Pb in the radical zone of sandy everlasting. These plants revealed features of hyperaccumulator because of the uptake of considerable lead quantities (Rascio and Navari-Izzo 2011). According to World Health Organization, a permissible lead content within therapeutic plants is 10 mg Pb·kg^{-1} d.w., thus, the studied sandy everlasting should not be utilised in phytotherapy (WHO 1998).

The accumulation of trace elements in soils, especially in a form available to plants, can result in their excessive uptake and concentration in plant tissues which suggests that quality of plant material (Basta *et al.* 2005) does not correspond to the standards applied in food processing and phytotherapy. In relation to studied plants mentioned above this issue concerns sandy everlasting.

CONCLUSIONS

1. Studied soils were not polluted by heavy metals in the surface horizon. The mobile fractions of metals extracted with DTPA were largely element-dependent from mean 15.1% of total content for Cu to mean 1.4% for Fe.

2. Among studied plants the sandy everlasting contained the biggest amount of Cu, Mn, however, content of Pb in the dry weight was higher than 10 mg·kg^{-1}, which points that plants sampled from studied areas should not be utilised in phytotherapy.

3. The values of bioaccumlation factor point that all studied plants accumulated Hg and Zn in the highest degree.

4. Stinging nettle revealed the highest phytoaccumulation properties in comparison to other plants.

5. To collect herbaceous plants for phytotherapy it is necessary to monitor the harvest places, especially in relation to trace elements content.

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