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ORIGINAL PAPER

SPATIAL DISTRIBUTION OF TRACE ELEMENTS IN SHALLOW MOUNTAIN PEATLANDS, THE STOŁOWE MOUNTAINS (SW POLAND)*

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Abstract

The objective of this research was to assess the total concentrations and pools of trace elements in the surface layers of organic soils in the Stołowe Mountains (Central Sudetes). Trace element concentrations are discussed in relation to the site variability and soil properties. Moreover, an attempt is made to assess the dominant source of trace elements in the peatlands, by comparison of different types of peatlands (fen – peat bogs). Peat coring and sampling were carried out along five research transects in September 2013. In total, 19 sampling plots were established within 5 shallow peatlands. The following soil properties were determined in the sampled peat material: ash content, bulk density, degree of peat decomposition, soil pH, total organic carbon (TOC) and the total content of Cu, Pb, Zn and Cd. The pools of trace elements were calculated for the 0-30 cm topsoil layer. In the study, no statistically significant correlations were found between an altitude and trace element content, which might be the result of small differences in elevation between the study sites. Additionally, this result might have been caused by differences in the organic matter content and soil pH among the study sites, confirmed by statistical analyses. Trace element concentrations and pools in peat soils are the result of both air deposition and groundwater interflow. Fen peatlands obtain a large load of elements mainly from substrates. The highest air-borne pollutant deposition rates (Pb in particular) were recorded in the 10-20 cm layer of the peat bog soils, what is due to the historical deposition of pollutants from the former "Black Triangle" region.

Keywords: organic soils, mountain soils, soil pollution, heavy metals, Sudetes Mts.

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INTRODUCTION

The impact of human activities on mountain peatlands is weaker and more recent than in lowland peatlands (Glina et al. 2017). However, mountain ranges in the Sudetes are situated within an area influenced by contamination from the former “Black Triangle” region (Fabiszewski, Wojtuń 1994). The border area between Poland, Czech Republic and Germany, the so-called “Black Triangle”, has been one of the most industrialized (electric power plants, ferrous and non- ferrous smelters, mining facilities) and highly polluted areas in Central Europe since the mid-20th century (Kucharczak, Moryl 2010). These industrial operations strongly affected the landscape in the region, causing the worst damage especially at altitudes above 700 m a.s.l (Markert et al. 1996). Trace elements can be transported by wind over long distances from their emission sources (Meyer et al. 2015) or they can migrate with surface or subsurface waters from adjacent areas (Shotyk 2002). Research into the accumulation of trace elements in soils is of great importance because of their influence on natural ecosystems (Gerdol, Bragazza 2006, Plak et al. 2016), the growth and development of living organisms in particular (Chojnicki et al. 2015). There is a considerable number of investigations demonstrating trace element distributions in organic soils from different parts of Europe (e.g. Gerdol, Bragazza 2006, Meyer et al. 2015) and the Sudetes mountains as well (e.g. Ettler, Mihaljevič 1999, Bogacz 2009, Waroszewski et al. 2009*b*, Glina, Bogacz 2013, Wojtuń et al. 2013). However, peat soils in the Stołowe Mountains (Central Sudetes) have been poorly explored in terms of trace element accumulation (Bogacz 2002). Peatlands are considered to be sentinel ecosystems in studies on anthropogenic contamination of the natural environment (Meyer et al. 2015, Bao et al. 2016). However, mainly ombrotrophic peatlands have been studied in terms of ecosystem contamination in the Sudetes (Glina, Bogacz 2013). Meanwhile, fen peatlands (fed with groundwater) can also make a significant contribution to this research, as was proved by Bao et al. (2016).

The objective of this research was to assess the total concentrations and pools of trace elements in the surface layers of organic soils in the Stołowe Mountains. The spatial variation of trace elements presented below is discussed in relation to the site variability, landform and soil properties. Moreover, an attempt has been made to assess the dominant source of trace elements in the peatlands by comparing different types of peatlands (fen – peat bogs).

MATERIAL AND METHODS

Site location and characteristics

The Stołowe Mountains are located in the Central Sudetes, south-west Poland (Figure 1). The mean annual air temperature does not usually exceed 5°C. The mean annual precipitation sum ranges from 750 to 920 mm (Gałka et al. 2013). The altitude of the Stołowe Mountains varies between 391 and 919 m a.s.l., with the highest summits of Skalniak Plateau 840-850 m a.s.l, Szczeliniec Mały 895 m a.s.l, and Szczeliniec Wielki 919 m a.s.l. This part of the Sudetes is mainly formed from upper Cretaceous sandstones, with concurrently present fine-grained sandstones, siltstones (mudstones) and claystones (Waroszewski et al. 2015). The organic soils, which are the subject of this study, mainly occur at an elevation of between 500 and 900 m a.s.l. and cover about 132 ha of the Stołowe Mountains (Bogacz 2002).

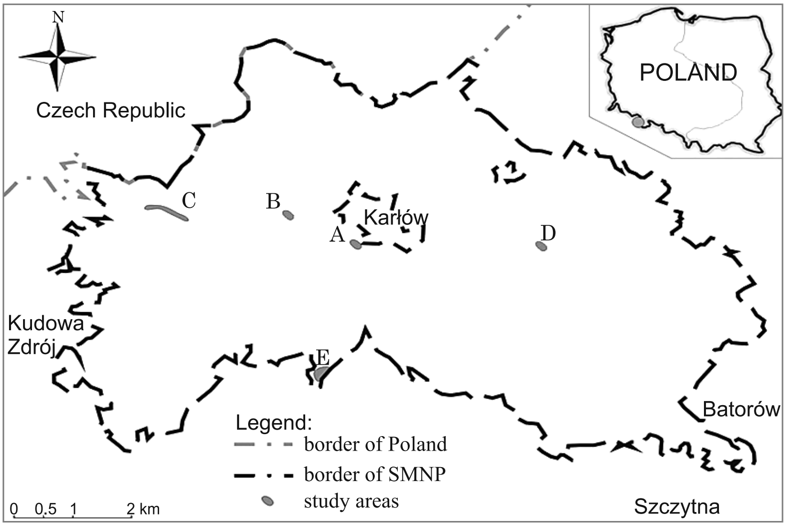

Fig. 1. Location map of the study sites within the border of the Stołowe Mountains National Park

For this research, five shallow peatlands were chosen, differentiated in terms of the ecological type (fen-peat bog), elevation and type of water supply (Table 1). In total, 19 sampling plots (5 x 5 m) were established within 5 research transects (Figure 2). The sampling sites are located in areas with varying exposure to the southwest winds, which dominate in the Stołowe Mountains (Glina et al. 2017). Study sites C and E lay on the elevated summits of the hills Skalniak and Rogowa Kopa, respectively. They are the most exposed to atmospheric deposition among the investigated peatlands, lacking any orographic barriers in the immediate vicinity. The other peatlands (site A and B) are situated on the northern slopes of Skalniak Ridge (Glina et al.

Table 1

Characteristics of the sampling sites

Transect	Coordinates WGS 84 (N/E)	Elevation (m a.s.l.)	Type of peatland	Type of water supply	Underlying bedrock
A	*50°28’06.1”/16°20’25.2” **50°28’05.0”/16°20’21.8”	758-767	fen peatland	soligenic	sandstone/ siltstone
B	50°28’19.7“/16°19’41.5“ 50°28’21.8”/16°19’38.9“	792-799	fen peatland	soligenic	sandstone/ siltstone
C	50°28’27.8“/16°17’21.3“ 50°28’23.9“/16°17’48.8“	831-847	peat bog	ombrogenic-fluviogenic	sandstone
D	50°28’27.8”/16°23’28.6“ 50°28’23.9”/16°17’48.8”	716-718	peat bog	ombrogenic	sandstone
E	50°27’00.0”/16°20’12.7“ 50°26’53.5”/16°20’12.2”	743-753	transitional bog	ombrogenic-soligenic	siltsone

[*] the first sampling plot in the research transect; [**] the last sampling plot in the research transect;
Data in table after Glina et al. (2016*a*,*b*).

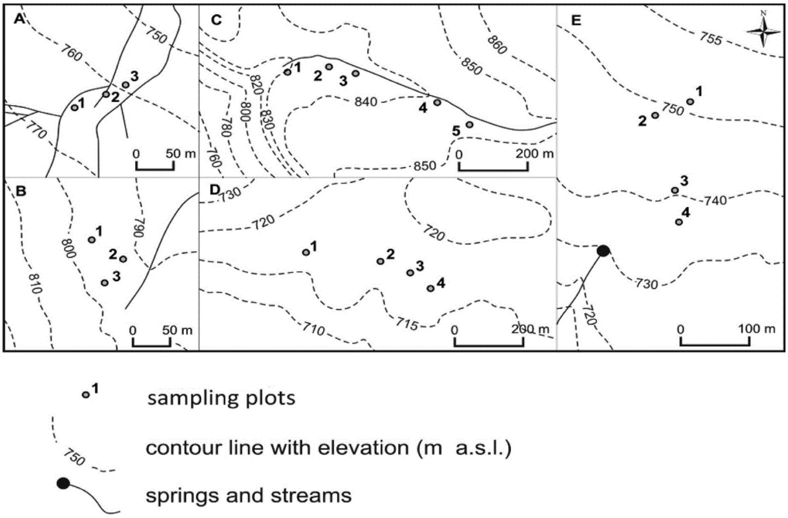

Fig. 2. Research transects within the study sites – a sketch

2016*b*) or in a wide, flat valley, deep in the heart of the Stołowe Mountains – site D (Glina et al. 2016*a*).

Sampling and sample preparation

Peat coring and sampling were carried out along five research transects (Table 1, Figure 2) in September 2013. Peat cores were collected using an Instorf peat sampler, at the central point of each sampling plot and 3-4 times in the immediate surroundings to avoid the impact of local soil variability. The 0.4 m long peat cores were placed in special plastic boxes and wrapped in polyethylene film. Additionally, undisturbed soil samples for bulk density determination necessary for trace element pool calculations were collected using stainless steel rings (100 cm^3) in three replicates from each sampling depth (0-10, 10-20 and 20-30 cm). In the laboratory, moist peat cores were sliced into 10 cm sections using a stainless steel knife. Peat material for analyses was sampled from standardized depth layers (0-10, 10-20 and 20-30 cm). Prior to analyses, sliced peat material was dried at room temperature, crushed in a clean agate mortar to yield homogenous powder and mixed. One representative sample (formed from 3-4 sub-samples) for each sampling plot and standardized depth was prepared for analysis.

Analysis methodology

The ash content, expressed as a percentage of the initial dry weight, was measured after incinerating air dried samples for 5 h in a muffle furnace at 550°C (BOJKO, KABAŁA 2014). Bulk density was determined on the basis of sub-samples with intact structure, which were dried to constant weight at 105°C. The degree of peat decomposition was determined from the fiber content in peat samples. Fibers were separated from peat samples by sieving rubbed peat on a 0.15 mm mesh under running tap water. For pH measurements, suspensions were prepared using dry peat mixed with 1M KCl at the 1:5 ratio (KABALA et al. 2016). Total organic carbon (TOC) and total nitrogen (TN) were determined, respectively, by catalytic dry combustion at 600°C in a Ströhlein CS-mat 5500 analyzer and by the Kjeldahl method using a Büchi analyzer. Total concentrations of selected trace elements (Cu, Pb, Zn, Cd) were determined on a Spectra AA 220 FS atomic absorption spectrometer (Varian) with background correction, after acid digestion. Peat samples (1 g) were placed in a heating block and digested with 5 ml of nitric acid (ultra pure 65%) and 1 ml of perchloric acid (ultra pure 70%) at 130°C for 12 h (ISO 11466). After dilution to 50 ml, samples were analyzed. Analyses of the total content of trace elements were carried out based on reference samples RTH 907 from the *Wageningen Evaluating Programs for Analytical Laboratories*. The recovery level was 94% for Cd, 95% for Zn and Pb and 96% for Cu. The above analyses of all peat samples were performed in triplicate. Pools of trace elements (for 0-30 cm) were calculated using the formulas: element pool ($g\ m^{-2}$) = a ($mg\ kg^{-1}$) $\cdot$ b ($g\ cm^{-3}$) $\cdot$ c (mm)/1000 (a – element content, b – bulk density, c – depth). To test the statistical significance of trends in trace element distribution among the study sites, the following analyses were performed: Pearson correlation coefficients, Principal Component Analysis (PCA) and ANOVA analysis of variance with *post-hoc* Tukey tests. The PCA diagram (Figure 3) presents the study sites (points) as well as the variables (vectors) on the plane of two principal components which together explain 92.24% of the total variation. Statistical analysis was supported by Statistica 13.1 (StatSoft Inc.) software.

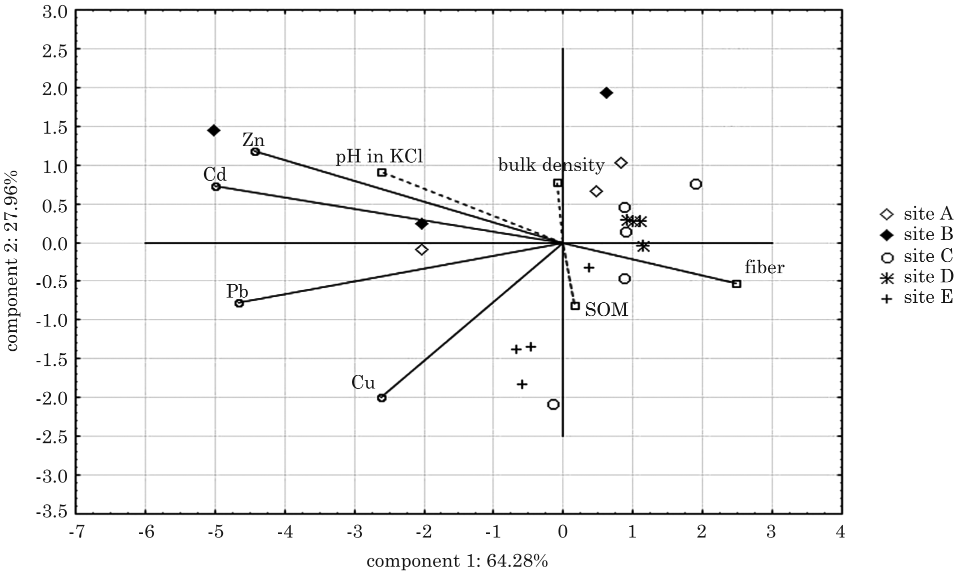

Fig. 3. Principal component analysis (PCA) of the soil properties and trace elements content

RESULTS AND DISCUSSION

Basic soil properties

The topsoil layers consisted of sapric, hemic and fibric peat (Table 2), according to the percentage fiber content (D'Amore, Lynn 2002). The ash content varied over a wide range. The lowest mean content of mineral particles was observed in the soils from study site D (raised bog), while the highest mean content was recorded in the surface soil horizons from fen peatland B.

Table 2

Selected properties of study soil layers (*n* = 57)

Study site	Fiber content (%)	Bulk density (g cm^{-3})	Ash (%)	TOC (%)	pH in KCl
A	4-10* 8**	0.16-0.25 0.18	16.3-51.0 24.4	23.2-41.4 37.6	5.2-5.9 5.4
B	2-38 11	0.14-0.40 0.22	10.0-77.6 30.6	12.2-45.1 28.4	3.7-5.5 4.8
C	6-85 38	0.11-0.43 0.20	3.60-82.2 25.9	14.5-46.7 34.3	2.9-4.0 3.3
D	12-58 43	0.10-0.35 0.14	2.10-23.8 8.90	38.2-52.5 46.5	2.8-3.0 2.9
E	5-75 15	0.14-0.35 0.19	11.0-64.7 26.0	16.9-40.9 34.8	3.5-3,9 3.7

* range, ** mean

Regarding bulk density values, a similar tendency was observed. Both of the described parameters were similar to previously published results of studies on organic soils from other peatlands in the Central Sudetes (Bogacz 2002, 2009). Surface organic soil layers (0-30 cm) were slightly to strongly acidic (Table 2), mean values of pH in KCl ranged from 2.9 (peat bog D) to 5.4 (fen peatland A). The mean total organic carbon (TOC) content ranged from 12.2 to 52.5% (Table 2). The highest TOC was determined in soils from peat bogs (sites C and D), whereas the lowest one was in soils from fen peatland B. In particular, low TOC content was observed in soil horizons enriched with mineral material (ash) – Table 2. A noticeable influence of the fiber content and added mineral material on the TOC content in mountain organic soils has already been described by D.Amore, Lynn (2002), Bogacz et al. (2012).

Concentrations of trace elements

The total content of elements in topsoil layers ranged from 2.15 to 28.6 mg kg^{-1} for Cu, from 0.10 to 7.10 mg kg^{-1} for Cd, from 20.5 to 279 mg kg^{-1} for Pb and from 6.61 to 235 mg kg^{-1} for Zn (Figures 4-7). The highest amounts of Cu were determined in soils from site E – the mean content 11.5 mg kg^{-1}. In the case of Cd and Zn, soils along research transects A and B were especially rich in these trace elements (Figures 6 and 7), whereas the highest mean concentrations of Pb (157-167 mg kg^{-1}) were noticed in surface soil layers from sites B and E. The Pb concentration of 150 mg·kg^{-1} is often referred to as the maximum tolerable one for soil biota. This fact, together with the acidic soil reaction and high content of soil organic matter, indicates an elevated risk of Pb ecotoxicity (Szopka et al. 2013). Among the study sites, the lowest amounts of trace elements were observed in the top 30 cm of peat bog soils. The zinc and copper concentrations recorded in soils were close to natural levels for organic soils (Figures 6 and 7), defined as 14 mg kg^{-1} for Cu and 30-120 mg kg^{-1} for Zn. The cadmium content in some cases

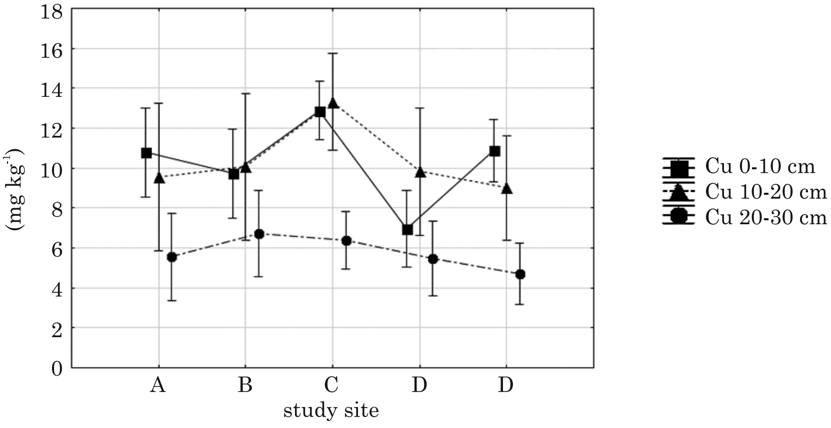

Fig. 4. Copper content in the surface soil layers (mean + SD; unit: mg kg^{-1})

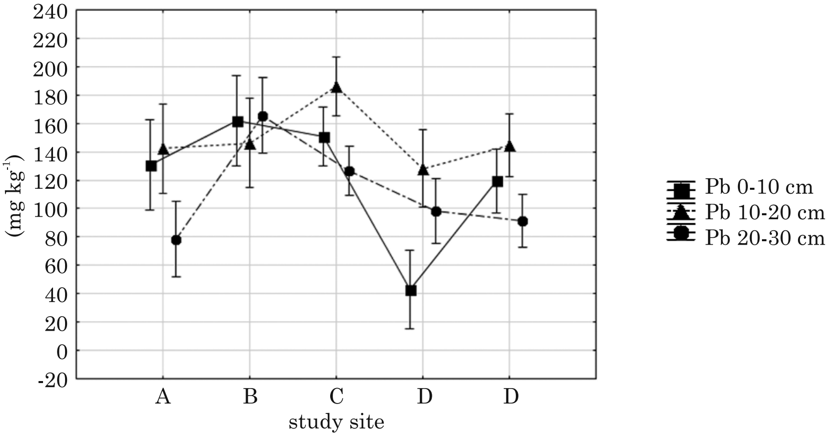

Fig. 5. Lead content in the surface soil layers (mean + SD; unit: mg kg^{-1})

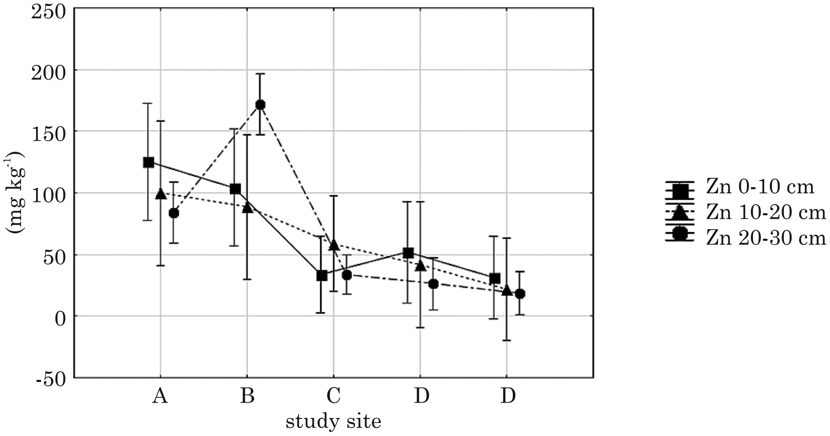

Fig. 6. Zinc content in the surface soil layers (mean + SD; unit: mg kg^{-1})

(fen peatlands A, B) was much above average concentrations in organic soils (0.2-1.05 mg kg^{-1}).

In most of the analyzed topsoil layers, Pb was found to exceed the content of Zn (Figures 5, 6). WAROSZEWSKI (2009*b*) reported that this corresponds to imbalance of natural proportions between trace elements and is the earliest soil pollution symptom. Anthropogenic accumulation of lead in the study soils is confirmed by wide differences between the minimum and average content (Figure 5), indicating local imissions of air-borne pollutants. Our analysis of Pb content at each of the sampling depths (0-10, 10-20, 20-30 cm) showed the highest content in the 10-20 cm layer (Figure 5). Radiocarbon age of layers with the highest Pb content (sites C, D and E) was dated by GLINA et al. (2017) to the second half of the 20th century. It can therefore be concluded that any recorded concentration (however small) is an

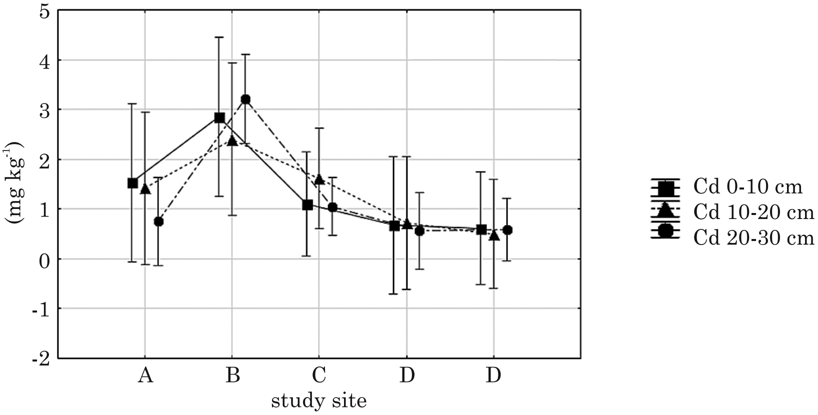

Fig. 7. Cadmium content in the surface soil layers (mean + SD; unit: mg kg^{-1})

effect of the historical deposition of industrial pollutants from fossil-fuel burning in the “Black Triangle” region. Elevated content of Pb in the uppermost layers of soils (Ettler, Mihaljevič 1999, Karczewska et al. 2006, Waroszewski et al. 2009*b*, Glina, Bogacz 2013, Szopka et al. 2013) and lake sediments (Malkiewicz et al. 2016), on both the Polish and Czech sides of the Sudetes, is also described in the literature. The Pb (mg kg^{-1}) content found in soils from the Izera Mountains (Ettler, Mihaljevič 1999, Glina, Bogacz 2013), as well the Karkonosze Mts (Ettler, Mihaljevič 1999, Waroszewski et al. 2009*b*) was the highest in the soil organic horizons. Other papers have confirmed that the greatest amounts of pollutants were deposited in the Karkonosze range (Suchara, Sucharová 2004). On the other hand, results described by Zhang et al. (2016) indicated that measured Pb, Zn, Cu and Cd) content in soils from the Kłodzko Valley (in close vicinity to the Stołowe Mountains) was definitely lower than the one reported in this paper. It can be concluded that the mountainous areas of the Sudetes were more exposed to the deposition of pollutants in comparison to other lower lying areas. In the Sudetes, south-western winds bring around 50% of air-borne pollutants (Liana 2010). The highest ranges act as an orographic barrier that makes contaminant depositions much larger than elsewhere (Szopka et al. 2013). It should be noted that the imission of anthropogenic pollution in the Central Sudetes is currently rather low, which is confirmed by the low lead content in the 0-10 cm soil depth (Figure 4). Such observations were also described by Karczewska et al. (2006) and Waroszewski et al. (2009*a*,*b*) in topsoil organic layers from the western Sudetes. A significant decrease in the lead content in Sphagnum mosses from ombrotrophic peatland in 2011 noticed by Wojtuń et al. (2013) is also in line with these findings.

In this study, no statistically significant correlation were found between an altitude and the trace element content (Table 3). This may be the result of small differences in elevation between the study sites (Table 1). Additionally, this might have been an effect of differences in the organic matter

Table 3

Pearson coefficients of correlations between trace elements and soil properties (n = 57)

Elements	Altitude	pH	TOC	Fiber	Ash
Copper (Cu)	-0.081	-0.024	0.410*	-0.048	-0.419*
Cadmium (Cd)	0.042	0.469*	0.006	-0.296*	-0.021
Lead (Pb)	0.037	0.165	0.176	-0.235	-0.203
Zinc (Zn)	-0.017	0.707*	-0.019	-0.392*	0.011

* significant at $p < 0.05$

content and soil pH among the study sites, which was confirmed by the PCA analysis (Figure 3) and Pearson coefficient of correlation (Table 3). Our results are in agreement with Szopka et al. (2013), who reported that there was no simple relationship between a site's altitude and its trace element content in the Karkonosze Mts. However, others, e.g. Gerdol, Bragazza (2006), Glina, Bogacz (2013), Meyer et al. (2015), have reported an increasing trace element content (Pb in particular) in soils with an increasing site altitude in various mountain ranges in Europe.

Spatial variability of trace element pools

The pools of trace elements calculated for the uppermost 0-30 cm soil layer showed the dominance of lead among other elements (Table 4), and the following order Pb > Zn > Cu > Cd. In the case of Pb, Zn and Cd, the highest pools were computed in topsoil from fen peatlands (site B), whereas the highest amounts of copper (Cu) accumulated in soils were observed in transitional bog (site E). These results showed some distinct local variability of the trace element pool distribution in the shallow mountain peatlands. As reported before, this might be an effect of canopy (Hernandez et al. 2003) and most likely due to local differences in the deposition of air-borne elements (Szopka et al. 2013) or water supply type (Bao et al. 2016). Another factor, which appears to be the key one for fen peatlands in particular, which are fed by groundwater (rich in minerals, as demonstrated by Glina et al. 2016*b*) is a large load of elements that may be obtained from substrates (sandstone/siltstone bedrock). Our results clearly showed that pools of trace elements in fen peatlands (sites A and B) were the highest in the uppermost part of the slope (Table 4), where local seepage (fractured-fed springs from sandstone/siltstone contact zone) of groundwater occurs. Our observations confirmed that peat behaved like a "sponge", capturing a load of elements from substrates (weathered bedrock) and releasing small amounts. This explains why we observed lower amounts of trace elements accumulated in soils in the lower part of sloping fen peatlands (plots 1, 2, 4, 5 at sites A and B). Higher amounts of trace elements accumulated in fen peatlands than in peat bogs (Table 4)

Table 4

Trace element pools in the surface soil horizons

Study site	Sampling plot	Depth (cm)	Trace elements pools calculated (g m^{-2})							
			Cu		Pb		Zn		Cd	
A	1	0-10	0.16	0.39	2.18	6.04	1.59	4.27	0.02	0.05
		10-20	0.13		2.24		1.31		0.02	
		20-30	0.10		1.62		1.37		0.01	
	2	0-10	0.16	0.41	1.79	4.86	1.88	4.34	0.02	0.05
		10-20	0.15		2.04		1.45		0.01	
		20-30	0.10		1.04		1.01		0.02	
	3	0-10	0.21	0.56	2.66	8.17	2.54	7.31	0.04	0.11
		10-20	0.22		3.00		2.48		0.04	
		20-30	0.13		2.51		2.29		0.03	
B	4	0-10	0.10	0.38	1.28	5.89	1.64	8.01	0.04	0.14
		10-20	0.14		2.39		3.48		0.06	
		20-30	0.14		2.22		2.89		0.04	
	5	0-10	0.19	0.47	4.97	13.5	1.95	8.37	0.05	0.22
		10-20	0.15		4.61		2.74		0.07	
		20-30	0.13		3.87		3.68		0.10	
	6	0-10	0.24	0.67	4.68	14.9	4.65	14.4	0.13	0.35
		10-20	0.27		5.43		5.17		0.14	
		20-30	0.16		4.74		4.61		0.08	
C	7	0-10	0.14	0.43	2.65	6.64	0.58	1.85	0.01	0.03
		10-20	0.18		2.20		0.51		0.01	
		20-30	0.10		1.78		0.77		0.01	
	8	0-10	0.16	0.34	1.55	4.17	0.41	0.84	0.01	0.03
		10-20	0.13		1.81		0.26		0.01	
		20-30	0.05		0.81		0.17		0.01	
	9	0-10	0.16	0.54	1.56	5.65	0.26	0.86	0.01	0.03
		10-20	0.22		2.38		0.31		0.01	
		20-30	0.16		1.70		0.29		0.01	
	10	0-10	0.11	0.30	1.79	5.96	0.27	0.95	0.01	0.04
		10-20	0.10		2.04		0.32		0.01	
		20-30	0.09		2.14		0.35		0.02	
	11	0-10	0.13	0.38	1.71	8.98	0.48	1.23	0.01	0.03
		10-20	0.16		4.18		0.44		0.01	
		20-30	0.10		3.08		0.31		0.01	
D	12	0-10	0.08	0.37	0.56	4.49	0.44	1.48	0.00	0.02
		10-20	0.19		2.12		0.59		0.01	
		20-30	0.10		1.81		0.45		0.01	
	13	0-10	0.08	0.31	0.47	3.09	0.54	1.43	0.01	0.03
		10-20	0.19		1.77		0.53		0.01	
		20-30	0.04		0.86		0.36		0.01	
	14	0-10	0.09	0.29	0.70	3.79	0.82	1.74	0.01	0.03
		10-20	0.07		1.22		0.49		0.01	
		20-30	0.13		1.87		0.43		0.01	
	15	0-10	0.09	0.35	1.35	5.25	0.50	1.56	0.01	0.03
		10-20	0.16		2.42		0.74		0.01	
		20-30	0.09		1.47		0.32		0.01	
E	16	0-10	0.13	0.62	1.91	7.70	0.38	1.36	0.02	0.06
		10-20	0.23		2.33		0.42		0.02	
		20-30	0.26		3.47		0.56		0.02	
	17	0-10	0.17	0.82	2.08	10.6	0.53	2.29	0.02	0.11
		10-20	0.54		5.30		0.62		0.03	
		20-30	0.10		3.25		1.15		0.06	
	18	0-10	0.20	0.49	2.06	7.52	0.61	2.45	0.01	0.04
		10-20	0.20		3.13		0.99		0.02	
		20-30	0.09		2.33		0.86		0.01	
	19	0-10	0.27	0.64	2.82	9.42	0.51	2.14	0.02	0.06
		10-20	0.24		3.53		0.64		0.02	
		20-30	0.13		3.08		0.98		0.02	

in the Central Sudetes, thus revealing that anthropogenic pollution (atmospheric deposition) in the study area is rather low. The source of contamination can be distinguished because ombrotrophic peatlands obtain most heavy metals directly from precipitation and dry deposition (MEYER et al. 2015). Differences between fen peatlands and peat bogs in relation to Cd, Pb and Zn pools in the topsoil (0-30 cm) layers were confirmed by the ANOVA analysis of variance with a *post-hoc* Tuckey test (Table. 5). Multiple comparisons of the study sites showed that three homogenous group can be distinguished. In the case of Pb and Cd accumulation in the topsoil, site B differs significantly from the other study sites, whereas sites A, C and E belonged to the same group. Once calculated, the pools of Zn allowed the separation of transitional bog (E) and peat bog (C) into one homogeneous groups, while fen peatlands A and B constituted two separate groups. The amount of copper accumulated in the surface peat layers did not differentiate the study sites (Table 5). The weak soil pollution identified in the Stołowe Mountains could be explained in two ways: firstly, most of the pollution load has been deposited on orographic barriers located in the Western Sudetes (e.g. the Karkonosze Mts); and secondly, dense forest stands (spruce monoculture) which have covered the study peatlands since the late 19th century (GLINA et al. 2017) have protected these areas against wind transport (RÖSH 2000).

Table 5

ANOVA analysis of variance (trace elements pools in 0-30 cm) – multiple comparison with Tuckey test ($n = 57$, $p < 0.05$)

Study site	Cu	Pb	Zn	Cd
	(g m^{-2})			
A	*a*	*ab*	*b*	*a*
B	*a*	*b*	*c*	*b*
C	*a*	*ab*	*ab*	*a*
D	*a*	*a*	*a*	*a*
E	*a*	*ab*	*ab*	*a*

a,*b*,*c* – homogeneous groups of the Tuckey multiple comparison test

CONCLUSIONS

To the best of our knowledge, this study provides the first examination of the accumulation and distribution of trace elements in various shallow peatlands in the Central Sudetes (Stołowe Mountains). Our data provide evidence that trace element concentrations and pools in peat soils are the result of both air deposition and groundwater interflow. Fen peatland ecosystems, where the highest concentrations of measured trace elements were noted, obtain a load of elements mainly from substrates. The highest levels of air-borne pollutant deposition (Pb in particular) were recorded in the 10-20 cm layer of the peat bog soils. This might be the effect of the historical deposition of pollutants from the former “Black Triangle” region. Local variability of trace element content and pool distribution is an effect of selected soil properties (e.g., organic matter content and pH) and type of water supply in particular. Our results are crucial for the current and future management of peatland ecosystems in the Central Sudetes. Moreover, this study indicates the importance of the role of the historical deposition record in future research on pollution in peatlands using advanced analytical methods.

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