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TECHNOGENIC AND GEOGENIC MAGNETIC SUSCEPTIBILITY OF MOUNTAIN FOREST SOILS ON EXAMPLE OF FOREST DIVISION KAMIENNA GÓRA

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Abstract: The Sudety Mountains are located close to industrial areas of Germany, Poland and the Czech Republic and are the most polluted Polish mountains. Among air pollutants such as SO_2, NO_x, fly ashes from local and transboundary power plants emission have a significant input. In determination of soil pollutants, magnetic susceptibility measurements find application. The use of magnetic measurements as a proxy for chemical methods is possible because air pollutants and magnetic particles are interrelated. The major sources of air pollution in the Sudety Mountains are fly ashes from burning process of fossil fuels. This paper presents content and distribution of heavy metals in soil profiles, depending on their natural or industrial origin and the results of magnetic susceptibility measurements.

INTRODUCTION

The area of Forest Division Kamienna Góra covers 15526 ha and belongs to Region (VIII) of the Sudety Mountains, which are among the oldest mountain ranges in Europe. In morphological structure a distinguishing diversity of landscapes as an effect of rich geological history of this area is found. The soils of that region have weathering origin from shallow profile in higher part of mountains to middle and deep profile in subsidence.

The most of forest soils of that region contain considerable amounts of heavy metals such as lead, zinc and cadmium, the highest concentrations of which are observed in upper horizons. The magnetic susceptibility (MS) measurements found application in monitoring and assessment of the level of contamination of soils, especially by airborne pollutants. Magnetic iron particles are associated with hazardous pollutants such as heavy metals and as component of the industrial dust, are finally deposited on soil surface. Research of soil magnetic susceptibility of Poland shows diversity. Higher values of magnetic susceptibility (MS) are noted in soils of Southern Poland along the border with Slovakia, the Czech Republic and Germany, from Krakow through Upper Silesia to Lower Silesia. The reason for such spatial distribution of MS is emission of iron compounds related to burning processes of hard and brown coal. Metallurgy as well as coke plants and cement industry (Opole region) have significant influence on high values of MS, especially on areas of Krakow and Upper Silesia. In the Sudety Mountains region, technogenic influence on MS values is lower, particularly under organic horizons of soil profile. Diversification of parent rocks such as basalts, amphibolites, serpentines and phyllites, rich in ferrimagnetics affect magnetic susceptibility enhancement. Distribution of MS in soil profiles changes regardless of the soil type, but the fly ashes chemical content and level of deposition [8]. The aim of this work is to find relation between influence of parent rock and fly ash pollution on magnetic susceptibility of forest soils.

OBJECTS AND METHODS

Six profiles of soils localized in Forest Division Kamienna Góra were examined. Each evolved on different parent rock, under different forest stand and in different terrain configuration (height above sea level, slope gradient and orientation). The diagnosis of the soil profiles was done according to Polish Forest Soil Classification 2000 [2] and World Reference Base for Soil Resources 1998 [12].

Profile No. 1 (Skeleti-Protoalbic Cambisol). Located in the West Sudety Mountains at 1000 m a.s.l, northern orientation, slope gradient 6–8°, parent rock – phyllite shale. Type of humus: mor. Forest stand: die-back spruce stand after ecological disaster.

Profile No. 2 (Skeleti-Dystric Cambisol) Located in the West Sudety Mountains at 800 m a.s.l., western orientation, slope gradient 20°, parent rock – amphibolite. Type of humus: moder. Forest stand: beech timber forest.

Profile No. 3 (Skeleti-Haplic Podzol (Rustic)) Located in the Middle Sudety Mountains at 720 m a.s.l., southern orientation, slope gradient 25°, parent rock – porphyry. Type of humus: mor. Forest stand: spruce stand with a single admixture of beech.

Profile No. 4 (Dystric Cambisol) Located in the Middle Sudety Mountains at 520 m a.s.l., south-western orientation, slope gradient 12°, parent rock – "kwadrowe" sandstone. Type of humus: moder. Forest stand: spruce stand with a single admixture of beech, larch, and pine.

Profile No. 5 (Skeleti-Dystric Cambisol) Located in Middle Sudety Mountains at 550 m a.s.l., north-western orientation, slope gradient 15°, parent rock – conglomerate of alkali magma rocks. Type of humus: moder. Forest stand: beech stand.

Profile No. 6 (Rendzic Leptosol (Cambic)) Located in the West Sudety Mountains at 700 m a.s.l., south-western orientation, slope gradient 10°, parent rock – dolomite covered by magma rock – mantle. Type of humus: moder. Forest stand: spruce stand with a single admixture of beech and sycamore seed trees.

The six soil profiles were examined for physic-chemical parameters and magnetic susceptibility measurements (mass specific susceptibility [χ]) for each horizon. Soil samples were air dried and sieved through 1 mm screen in the laboratory to separate the soil skeleton. Particle size analysis was determined by sieve and aerometer methods by Casagrande'a in Prószynski modification (Tab. 1). Coarse fragment content in soils was determined in the field. Grain size and granulometry were determined according to classification of Polish Society of Soil Science. Soil pH in distilled water and 1 M KCl were determined by potentiometric method. Organic carbon was determined by modified Tiurin method (Tab. 2). Heavy metal content was determined by AAS method after the mineralization in mixture of 70% $HClO_4$ and concentrated HNO_3. Elements such as Ni and Cr were determined by ICP technique. All detail parameters regarding physic-chemical properties of the presented profiles and wide description of forest habitats are published in Atlas of Forest Soils in Poland [1].

Magnetic susceptibility is defined as a ratio of the material magnetization to the external magnetic field. Paramagnetic materials reach positive values of magnetic susceptibility whilst diamagnetic negative values [10]. The magnetic susceptibility (MS) was measured using the MS2 Bartington sensor in laboratory. It was expressed as the mass specific susceptibility (SI units of $\chi \cdot 10^{-8}$ [$m^3 \cdot kg^{-1}$]) (Tab. 3), which is the volume susceptibility divided by density of the material. The content of heavy metals in different horizons of soil profiles expressed in $mg \cdot kg^{-1}$ is strongly modified by density of horizons. To determine the correlation coefficient between magnetic susceptibility and heavy metals content in whole profile, factor D was applied. The volume density (D) expressed in $g \cdot cm^{-3}$ was worked out in the Department of Forest Soil Science of the Agricultural University of Cracow [1]. For calculation $D = 1.3773 \cdot e^{-0.0547 \cdot x}$ was assumed, where x – organic carbon content in %, which include samples with $C_{org.}$ content below 0.29% (Tab. 2).

Dust fall data were obtained from Forest Research Institute in Warsaw for three summer seasons (1988, 1989, and 1992) and winter season (1989). For comparison, dust fall results from neighbouring Forest Divisions (Śnieżka, Wałbrzych) are enclosed (Tab. 5) [3].

RESULTS AND DISCUSSION

Diversity of parent rock of examined soils is related with geological structure of the Sudety Mountains and present as follow: phyllite shale, amphibolite, porphyry, sandstone, conglomerate of alkali magma rocks and dolomite. The mechanical analyses were completed in laboratory and the soil horizons present textural classes from sand (S) (25–50 cm in profile No. 6) to silt loam (SiL) (7–26 cm and 26–76 cm in profile No. 5) according to USDA classification.

All soil profiles have low pH in uppermost horizons (below 4.5 in H_2O). Besides parent rock, climate and form of the organic matter, industrial pollutions have influence on low pH reaction. High amounts of anthropogenic Pb in organic horizons (O), (Tab. 3), significantly decrease activity of microrganisms' and decomposition of organic matter, what reflects the high content of organic carbon in uppermost horizons.

The magnetic susceptibility varies depending on horizon and parent rock. Comparison of coefficients of correlation between (MS) and heavy metals content expressed in $mg \cdot kg^{-1}$ and $mg \cdot dm^{-3}$ shows that expression of Cd, Pb, Fe and Mn in $mg \cdot dm^{-3}$ does not affect the tendency (correlation coefficient are positive) (Tab.2).

In the profiles No. 1 and No. 2 both technogenic and geogenic influence on magnetic susceptibility are observed. As opposed to the rest of soil profiles, magnetic susceptibility has the lowest values in upper horizons (Tab. 3).

Profile No. 1 (Skeleti-Protoalbic Cambisol) formed on phyllite shale, is rich in magnetic minerals. The highest content of iron, zinc and manganese accompanies the highest values of magnetic susceptibility in soil profile. Distribution of (MS) in soil profile suggests geogenic character. Correlation coefficients for Pb and Cd have negative values but for Fe, Zn, Mn, Ni, positive (Tab. 2).

Profile No. 2 (Skeleti-Dystric Cambisol) formed on amphibolite, rich in magnetic minerals, presents lithogenic character of magnetic susceptibility. High content of iron in

Table 1. Grain size distribution and chemical properties of soils

No. profile parent rock	Depth [cm]	Level	% fraction [mm]				$C_{org.}$ [%]	pH (H_2O)	pH (KCl)
			> 1	1.0–0.1	0.1–0.02	< 0.02			
1 phyllite shale	1–8	Of	0				31.76	3.4	2.5
	8–21	Oh/Ees	40				13.29	3.4	2.7
	21–56	BbrBfe	80	39	25	36		3.5	4.0
	56–110	BbrC	90	40	23	37		3.5	4.1
2 amphibolite	1–8	O/Ah	20				14.99	3.8	3.1
	8–25	A	40	25	36	39	2.84	4.3	3.7
	25–70	Bbr	40	33	30	37		5.2	4.1
	70–120	BbrC	90	38	27	35		5.3	4.1
3 porphyry	1–17	Ofh	0				25.14	3.5	2.7
	17–38	Ees	60	50	21	29	2.27	3.9	3.3
	38–49	Bh	70	48	34	18	5.84	4.1	3.7
	49–70	Bfe	70	34	35	31		4.2	4.0
	70–120	BC	90	58	19	23		4.3	3.9
4 "kwadrowe" sandstone	1–6	Ofh	0				23.52	3.7	2.9
	6–11	ABbr	1	67	18	15	1.19	3.8	3.1
	11–64	Bbr	1	38	31	31		4.1	3.8
	64–140	BbrC	30	41	34	25		4.8	3.6
5 conglomerate alkali magma rocks	2–7	Oh/A	30				16.3	3.7	3.0
	7–26	ABbr	40	21	28	51	1.12	4.2	3.5
	26–76	Bbr	40	19	28	53		4.1	3.8
	76–120	BbrC	90	43	19	38		4.1	3.8
6 dolomite covered magma rock-mantle	0–10	Ah	20				10.37	4.4	3.7
	10–25	ABbr	20	29	30	44	1.33	5.7	4.7
	25–50	IICca	90	92	5	3		7.9	7.9

Table 2. Correlation coefficients (r) between magnetic susceptibility and heavy metals content in soil profiles expressed in [$mg \cdot kg^{-1}$]/[$mg \cdot dm^{-3}$]

No. profile	Fe	Pb	Cd	Zn	Mn	Cr	Ni
1 phyllite shale	0.53/0.50	-0.65/-0.56	-0.64/-0.71	0.45/0.63	0.62/0.61	-0.06/0.30	0.71/0.72
2 amphibolite	0.85/0.63	-0.58/-0.40	0.36/0.80	-0.58/0.60	0.74/0.63	-0.45/0.34	0.72/0.83
3 porphyry	-0.55/-0.90	0.99/0.99	0.99/0.92	0.96/-0.81	-0.22/-0.57	0.45/-0.70	0.84/-0.48
4 "kwadrowe" sandstone	-0.19/-0.50	0.99/0.99	0.99/0.99	0.94/-0.20	-0.08/-0.50	0.90/-0.53	0.62/-0.37
5 conglomerate alkali magma rocks	-0.69/-0.90	0.99/0.99	0.99/0.99	0.83/-0.97	-0.91/-0.96	0.53/-0.91	-0.43/-0.92
6 dolomite covered magma rock-mantle	0.63/0.30	0.99/0.99	-0.49/-0.60	0.44/0.14	-0.62/-0.77	0.87/0.56	0.58/0.25

Table 3. Magnetic susceptibility (χ), volume density (D) and heavy metals content in soil profiles

Profile	Depth [cm]	Level	$\chi \cdot 10^{-8}$ [$m^3 \cdot kg^{-1}$]	D [$g \cdot cm^{-3}$]	Heavy metals x D [$mg \cdot dm^{-3}$]						
					Fe	Pb	Cd	Zn	Mn	Cr	Ni
1	1–8	Of	105.4	0.24	2036.2	39.8	0.17	14.4	46.3	4.6	3.4
	8–21	Oh/Ees	138.8	0.67	13986.6	41.0	0.07	19.4	212.2	11.3	7.3
	21–56	BbrBfe	119.4	1.38	57021.6	20.1	0.07	111.4	4501.6	45.8	34.8
	56–110	BbrC	181.0	1.38	52164.0	16.4	0.06	136.8	5575.2	32.3	50.6
2	1–8	O/Ah	224.6	0.61	17044.1	28.2	0.09	36.7	619.3	32.2	17.2
	8–25	A	445.4	1.18	43008.8	15.0	0.25	57.7	2455.8	36.1	49.4
	25–70	Bbr	357.7	1.38	50011.2	4.0	0.07	66.1	2365.3	24.7	36.4
	70–120	BbrC	289.6	1.38	47720.4	3.3	0.07	62.5	2805.5	22.6	42.8
3	1–17	Ofh	69.6	0.35	3713.8	44.0	0.16	16.9	107.2	4.5	4.5
	17–38	Ees	26.2	1.22	13645.3	12.8	0.06	30.6	347.8	10.0	4.7
	38–49	Bh	28.7	1.00	15528.8	12.7	0.05	30.2	269.0	12.9	8.3
	49–70	Bfe	31.5	1.38	17470.8	14.1	0.07	41.3	552.0	18.5	12.8
	70–120	BC	29.2	1.38	18285.0	12.1	0.10	31.9	874.9	11.2	9.8
4	1–6	Ofh	130.9	0.38	2157.3	44.9	0.15	16.0	132.3	7.3	4.8
	6–11	ABbr	3.3	1.29	2697.2	11.2	0.09	11.4	85.2	7.5	3.5
	11–64	Bbr	7.7	1.38	9894.6	12.0	0.07	17.5	567.2	11.9	7.0
	64–140	BbrC	3.1	1.38	17829.6	8.1	0.07	27.9	955.0	16.4	16.0
5	2–7	Oh/A	115.1	0.56	10491.8	95.2	0.08	44.6	684.4	15.0	11.9
	7–26	ABbr	28.4	1.29	26825.4	15.5	0.06	79.9	3669.1	30.4	27.2
	26–76	Bbr	33.6	1.38	30470.4	13.1	0.07	81.7	2953.2	38.0	29.8
	76–120	BbrC	23.5	1.38	37784.4	14.9	0.07	95.5	4353.9	31.7	39.3
6	0–10	Ah	108.0	0.78	21553.6	181.2	0.29	145.0	3996.0	33.4	16.9
	10–25	ABbr	40.9	1.28	43887.3	88.2	1.70	383.9	15718.8	46.6	37.5
	25–50	IICca	1.3	1.38	6927.6	6.8	0.99	45.4	12033.6	3.7	3.5

the profile have stronger influence on (MS) than high content of lead in organic horizon. Correlation coefficients in this profile are positive for iron, cadmium and nickel and negative for lead. (Tab. 2).

Profile No. 3 (Skeleti-Haplic Podzol (Rustic)) shows enhancement of magnetic susceptibility in the upper horizon ($69.6 \cdot 10^{-8}$ $m^3 \cdot kg^{-1}$) (Tab. 3). Parent rock (porphyry) is not rich in magnetic minerals; measurements in lower horizons gave results in range from 26 to $32 \cdot 10^{-8}$ $m^3 \cdot kg^{-1}$. Lead content is highest in the surface horizon, correlation coefficient between content of this element in all horizons and magnetic susceptibility is equal to 0.99, which suggests technogenic origin of Pb in this profile.

In the profile No. 4 (Dystric Cambisol), the highest magnetic susceptibility ($130.9 \cdot 10^{-8}$ $m^3 \cdot kg^{-1}$), (Tab. 3) has the organic horizon (Ofh). Parent rock ("kwadrowe" sandstone) is poor in magnetic minerals. Slope orientation (SW), which is in main direction of pollution influx and high Pb and Cd contents in upper horizon, suggests technogenic origin of these elements in soil profile. Correlation coefficient for magnetic susceptibility and lead and cadmium content equals 0.9 and confirms technogenic character of magnetic susceptibility.

In the profile No. 5 (Skeleti-Dystric Cambisol), highest magnetic susceptibility ($115.1 \cdot 10^{-8}$ $m^3 \cdot kg^{-1}$) (Tab. 3) is in horizon Oh/A. Parent rock (conglomerate of alkali magma rocks) is poor in the magnetic minerals. Slope orientation (NW), highest Pb content in the upper horizon and high correlation coefficient (0.9) between content of this element and magnetic susceptibility suggests technogenic origin of lead in this profile.

In the profile No. 6 (Rendzic Leptosol (Cambic)), the highest magnetic susceptibility ($108 \cdot 10^{-8}$ $m^3 \cdot kg^{-1}$) (Tab. 3) is in the horizon Ah and decreases with depth. Parent rock (dolomite covered by magma rock – mantle) is poor in magnetic minerals. Slope orientation (SW) is compliant with direction of long-range pollution influx from industry regions. The highest Pb content in upper horizon and correlation coefficient between content of this element in the profile and magnetic susceptibility suggest technogenic origin of lead in this profile (Tab. 2).

Research conducted in South of Poland on 42 forest soil profiles shows comparable results regarding distribution of heavy metals (Pb, Zn, Cd) in O/A horizons and their technogenic origin [6]. Correlation coefficients for Pb content and magnetic susceptibility are high in profiles developed on parent rocks poor in magnetic minerals (dolomites, sandstones, porphyries). In profiles developed on parent rock rich in magnetic minerals, they have negative values (Tab. 2). However, lead content in uppermost organic horizons is highest in all profiles, which suggests anthropogenic origin of this element, in profiles rich in magnetic minerals (Profile 1, 2), does not affect significantly magnetic susceptibility values.

Technogenic character of magnetic susceptibility in uppermost organic horizons is result of fly ashes deposition (Profiles 1, 2, 3, 4, 5, 6; Tab. 4). Geogenic character of magnetic susceptibility in examined soil profiles is confirmed by higher values in parent rocks compared to the uppermost organic horizons (Profiles 1, 2; Tab. 4). Pedogenic processes also affect (MS) in researched soils, it concerns accumulation horizons (B) of soils, formed on poor in ferromagnetics parent rocks (Profiles No. 3, 4, 5, 6; Tab. 4). Relocation and transformation of iron compounds and then other elements may significantly affect magnetic susceptibility of a soil profile.

Table 4. Magnetic susceptibility in soil profiles

Magnetic susceptibility character	Profile No. and parent rock					
	1 phyllite shale	2 amphibolite	3 porphyry	4 "kwadrowe" sandstone	5 conglomerate alkali magma rocks	6 dolomite covered magma rock-mantle
Technogenic	X	X	X	X	X	X
Geogenic	X	X				
Pedogenic			X	X	X	X

The magnetic properties of soils change due to the industrial and urban dust deposition. Most of industrial dusts contain significant fraction of ferrimagnetic particles that are produced during various high temperature technological processes or combustion of fossil fuels [8]. High magnetic susceptibility in uppermost horizons of forest soil profiles are related to species composition of forest stands. Norway spruce is the dominant species in the Forest Division Kamienna Góra and has the highest ability to retain air pollution compared to other tree species [11].

Lead, in spite of other emitted heavy metals, has the highest enrichment coefficient which is connected with physic-chemical properties and specific surface of ash from power station chimneys. Specific surface for chimney ash from the power station "Turów" is 3.96 $m^2 \cdot g^{-1}$ and is higher than fly ash 2.28 $m^2 \cdot g^{-1}$ [4]. These factors have influence on higher Pb content (compared to Zn content) in uppermost horizon of soil profiles and bogs of southern Poland, where the majority of power plants is located.

Table 5. Montly dust fall over Forest Division Kmienna Góra area [$g \cdot m^{-2} \cdot month^{-1}$], based on Forest Research Institute data [3]

Years	Śnieżka			Kamienna Góra			Wałbrzych		
	mean	max	month	mean	max	month	mean	max	month
1988	2.006	5.340	VIII	2.272	6.367	VII	2.355	6.877	IX
1989	1.431	16.025	VIII	1.536	5.962	V	2.051	7.072	V
1989/90	2.010	3.890	XII	1.733	9.781	X	1.792	4.886	II
1992	2.152	9.546	VII	1.763	4.845	VIII	3.022	11.318	VIII

Mean natural content of Pb in Polish soils is 18 $mg \cdot kg^{-1}$. In all profiles the content of Pb is highest in the uppermost organic horizons. Because of low migrations of this element, its natural distribution in soil profile reflects its content in parent rock. A reason of high values of Pb in soil profiles of the Sudety Mountains area is transboundary pollution influx from Germany and the Czech Republic, which was shown by Zwoździak [13]. Low households emission significantly contributes to air pollution in winter. The main directions of pollution influx in the Sudety Mountains are SW and W. The flow of air pollution from Germany is confirmed by data of magnetic susceptibility of soils along the Polish-German border. On the Southern part of the border, along the Sieniawa – Gubin line, magnetic susceptibility values range from 277–500$\cdot 10^{-8}$ $m^3 \cdot kg^{-1}$ and along the Słubice – Woliński National Park line from 50–200$\cdot 10^{-8}$ $m^3 \cdot kg^{-1}$ [9]. Higher Pb content over Zn in uppermost horizons of mountain soils is confirmed by Skiba for the Karkonosze Mountains [5]. Study of peat bog localized in Izerska Mountain Pasture showed in 0–5 cm layer: Zn content from 17.6 $mg \cdot kg^{-1}$ to 58.6 $mg \cdot kg^{-1}$ and Pb content from 72.4 $mg \cdot kg^{-1}$ to 201 $mg \cdot kg^{-1}$ and confirming relation between these elements [7]. Zinc is one of the most mobile metals in soil, due to its exchangeable forms and relations (compounds) with organic matter. The highest content of this element as well as of cadmium was found in ABbr horizon of Profile No. 6 (Tab. 3). Research conducted on Izerska Mountain Pasture showed high fluctuations of Zn content in the period from 800 to 2000 A.D. Significant increase of Pb and Cd content after 1800 A.D. was related to industrial development period [7].

Cadmium is an element strongly dispersed in rocks (higher concentrations are in alkali magma rocks and slates) and its average content is in the range of 0.03–0.22 $mg \cdot kg^{-1}$. In soils with pH range of 4.5–5.5, cadmium is very mobile whereas in higher pH values are immobilized. Natural content of this element in soil depends on its presence in the parent rock, but high anthropogenic influence causes its increase in soils. The highest content of Cd is in horizon ABbr (10–25 cm) profile No. 7 (Rendzic Leptosol Cambic). For the rest of soils, the highest content is noticed in surface organic horizons which suggest the anthropogenic origin of this element.

CONCLUSIONS

Magnetic properties of investigated soils reflect various influence of parent rock on the magnetic susceptibility values. In the examined profiles, the elements are of both lithogenic and anthropogenic origin. Sedimentary rocks, such as dolomite and "kwadrowe" sandstone (profile No. 4 and 6), have low concentration of magnetic minerals compared to metamorphic rocks such as amphibolite and phyllite shale (profile No. 1 and 2). Magnetic susceptibility of the examined forest soils has geogenic character in profiles No. 1 and No. 2, where anomalies of MS distribution are observed. Distinguishing between technogenic and geogenic magnetic susceptibility is possible because of the content and spatial distribution of heavy metals in soil profiles. In organic horizons, especially subhorizons Of and Oh, on the whole researched area, magnetic susceptibility had technogenic character and heavy metals (especially lead) occurred in relatively high amounts. Content of lead in upper horizons is higher than zinc content, which is characteristic for soils in the Sudety Mountains – region which is under influence of the fly ashes deposition. Ecological hazard for studied soils results from high Pb content and low pH reaction in organic horizons.

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TECHNOGENNA I GEOGENNA PODATNOŚĆ MAGNETYCZNA GÓRSKICH GLEB LEŚNYCH NA PRZYKŁADZIE NADLEŚNICTWA KAMIENNA GÓRA

Sudety są położone w pobliżu centrów przemysłowych Niemiec, Polski i Czech i są najbardziej zanieczyszczonymi polskimi górami. Pośród takich zanieczyszczeń jak SO_2 i NO_x istotną rolę odgrywają emisje pyłów lotnych pochodzących z lokalnych i przygranicznych elektrowni. W oznaczaniu stopnia zanieczyszczeń gleb znajdują zastosowanie pomiary podatności magnetycznej. Zastosowanie tego rodzaju pomiarów jako wsparcie metod chemicznych jest możliwe dzięki wspólnym relacjom między cząstkami magnetycznymi i samymi zanieczyszczeniami. Głównym źródłem zanieczyszczeń powietrza w rejonie Sudetów są popioły lotne pochodzące z procesu spalania paliw kopalnych. Praca przedstawia skład i rozmieszczenie w profilach glebowych metali ciężkich, w zależności od ich naturalnego bądź przemysłowego źródła pochodzenia oraz wyniki pomiarów podatności magnetycznej.