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MAGNETIC SUSCEPTIBILITY AND HEAVY METAL CONTENTS OF FOREST SOILS UNDER VARIABLE DOMINANT TREE SPECIES IN PRUHONICE PARK

MARZENA FERDYN, ZYGMUNT STRZYSZCZ

Institute of Environmental Engineering of the Polish Academy of Sciences, ul. M. Sklodowskiej-Curie 34, 41-819 Zabrze

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PODATNOŚĆ MAGNETYCZNA I ZAWARTOŚCI METALI CIĘŻKICH W GLEBACH LEŚNYCH W ZALEŻNOŚCI OD RODZAJU DRZEWOSTANU W PARKU W PRUHONICACH

Celem niniejszego opracowania było oszacowanie wpływu rodzaju drzewostanów na podatność magnetyczną i zawartości niektórych metali ciężkich w glebach leśnych. Badania prowadzone były na terenie starego parku w Pruhonicach (koło Pragi) w Czechach. Na stosunkowo małym obszarze parku znajdują się skupiska różnych gatunków drzew, będące pod wpływem takich samych czynników naturalnych i antropogenicznych (typ gleby, podłoże geologiczne, klimat, odległość od źródeł emisji). Do badań wybrano pięć drzewostanów szpilkowych (sosna, świerk, świerk kłujący, jodła, daglezja) i pięć drzewostanów liściastych (buk, dąb czerwony, dąb szypułkowy, grab, brzoza).

W terenie pomierzono podatność magnetyczną oraz pobrano po dwie próby glebowe (30-cm tuby o przekroju 2,5 cm) oraz ściółkę leśną spod każdego drzewostanu. W laboratorium pomierzono podatność magnetyczną wzdłuż profili glebowych oraz określono zawartości metali ciężkich (Pb, Cu, Fe, Cd, Zn, Mn) w ściółce leśnej.

Stwierdzono wysokie zawartości metali ciężkich w warstwie ściółki, jak również wysoki stopień korelacji między zawartością metali ciężkich a podatnością magnetyczną. Na podstawie uzyskanych wyników można wnioskować, że typ drzewostanu może mieć wpływ na zawartości metali ciężkich oraz podatność magnetyczną gleb leśnych. Wyższe wartości podatności magnetycznej zaobserwowano pod drzewostanami iglastymi. Jedynie w górnej warstwie gleby (0–1 cm) średnia podatność magnetyczna mierzona w terenie była wyższa dla drzew liściastych, na co wpływ mógł mieć świeży opad liści, ponieważ badania prowadzono jesienią.

Summary

The aim of the research was to study the influence of different tree stands on topsoil magnetic susceptibility and heavy metal contamination in the soil. The study was performed in the old park in Pruhonice (near Prague) in the Czech Republic. On the relatively small area of Pruhonice Park, five different coniferous tree species (pine, spruce, blue spruce, fir, Douglas fir) and five deciduous species (beech, red oak, common oak, hornbeam, birch) were found, growing in small clusters on the same geological background. Also other natural and anthropogenic factors such as distance from industrial and urban sources of pollution, type of soil, climate, etc. were similar. The magnetic susceptibility was measured directly in the field. Twenty topsoil cores 0.3 m long (2 under each tree species) were collected and also soil samples from under each tree (litter horizon) were taken. The magnetic susceptibility values of the topsoil profiles and of litter layer samples were obtained. Heavy metal analyses of surface samples (litter horizon) were also carried out.

The field magnetic susceptibility (κ) data are more or less comparable to the laboratory data (χ). High heavy metal contents corresponding to high magnetic susceptibility values are observed in the litter horizon. A positive correlation between magnetic susceptibility and some heavy metals was observed. The results suggest that the type of forest may also influence the values of magnetic susceptibility and heavy metal content. Generally higher magnetic susceptibility values were observed in the coniferous forest, except for the surface layer (litter horizon) where the κ values are lower than in the deciduous forest.

INTRODUCTION

Several field measurements and laboratory studies, using magnetic susceptibility as a method for pollution monitoring have been carried out recently [7, 9, 12]. Although magnetic susceptibility is a powerful tool for estimating the pollution level of the soils, some natural factors, such as mineral and chemical content contribute to this record [10]. The occurrence and distribution of heavy metals in the environment strongly constrain the magnetic susceptibility of the soil. The good relationship between both these parameters is already known [11]. The content of heavy metals in forest soils depends on many factors, such as pH, bedrock, type of pollution and tree stands as well [2, 5, 6]. The aim of this paper is to investigate the potential contribution of forest types to magnetic susceptibility and heavy metal content.

MATERIALS AND METHODS

SITE DESCRIPTION

It was very important for this study to find an area with a wide variety of tree species, which has been subjected to the same general environmental conditions. Following these guidelines, the old Pruhonice Park (near Prague) in the Czech Republic was chosen as the study area. It is situated south-east of Prague. The area of the park is about 244 ha and the park is divided in two parts: a large botanical garden and a preserve forest park, where the measurements were carried out. In the investigated area, the natural and anthropogenic factors such as the geological background, type of soil, climate, and the distance from industrial and urban sources of pollution are similar. The dust fall is not very high (the average is about 6 g/m^2 per month). The type of soil in this area is acid brown soil.

In the relatively small area of Pruhonice Park, five different coniferous and five deciduous tree species, growing in small clusters were found. The coniferous tree species included in the experiment are: spruce (*Picea abies* Karst.), Douglas fir (*Pseudotsuga menziessi* Franco), pine (*Pinus sylvestris* L.), blue spruce (*Picea pungens* Engelm.), fir (*Abies alba* Mill.), and the deciduous tree species: beech (*Fagus sylvatica* L.), red oak (*Quercus rubra* L.), common oak (*Quercus robur* L.), hornbeam (*Carpinus betulus* L.), and birch (*Betula verrucosa* Ehrh.).

FIELD MEASUREMENTS AND SAMPLING

The magnetic susceptibility was measured directly in the field using a "Bartington" MS2D sensor. Twenty topsoil cores, 0.3 m in length (2 under each tree species) were collected in autumn using a Huge sampler. Also a litter of 10 samples from under each tree species was taken.

LABORATORY MEASUREMENTS

The magnetic susceptibility of the topsoil profiles was obtained using a Bartington MS2F sensor.

Dried litter samples were ground and sifted through a 1-mm mesh sieve, and the magnetic susceptibility was measured using a "Bartington" MS2B sensor to obtain the specific magnetic susceptibility (χ). For determining heavy metals, the litter samples were dissolved in 2 M nitric acid (HNO_3) [3]. The heavy metal (Pb, Cu, Fe, Cd, Zn, Mn) content was determined by atomic absorption spectrometry using a Perkins Elmer 1100B spectrometer [8].

RESULTS AND DISCUSSIONS

The magnetic susceptibility (κ) data measured in the field are more or less comparable to the laboratory data (κ, χ) (Tab. 1). The differences are caused by the measuring equipment (different Bartington sensors) and by sample densities (in the field: loose, unconsolidated samples, in the laboratory: ground and compressed samples). In general, the mean value of κ along the soil profiles is higher for coniferous than for deciduous forests, especially below 5 cm depth (Tab. 2). The only exception is the uppermost layer, which may be the result of autumn sampling. The dust deposition on falling leaves may be the cause of the high values of magnetic susceptibility.

Table 1. Comparison of magnetic susceptibility values measured in the field (κ) and in the laboratory (χ, κ_{lf})

Tree species	χ $*10^{-8}[m^3kg^{-1}]$	κ_{lf} $*10^{-5}[SI]$	field κ $*10^{-5}[SI]$
Spruce	48.7	13.0	3.00
Douglas fir	38.7	11.2	11.58
Fir	20.2	6.3	21.67
Blue spruce	7.0	1.8	1.75
Pine	4.9	1.3	6.08
Red oak	22.6	6.4	15.00
Beech	18.4	5.5	17.70
Hornbeam	7.1	1.9	17.80
Common oak	5.0	1.2	11.90
Birch	3.1	1.0	7.00

Following the distribution of κ, the maximum values along all profiles are observed between 3–5 cm below the surface (fermentative horizon). The κ values increase down to 5 cm, reaching a value of 73×10^{-5} SI for the Douglas fir and about 12×10^{-5} SI for the birch. They then decrease to about 12×10^{-5} SI for the coniferous forests and to about 4×10^{-5} SI for the deciduous (Fig. 1).

The results of measuring the specific magnetic susceptibility and contamination of lead (Pb), copper (Cu), iron (Fe), cadmium (Cd), zinc (Zn) and manganese (Mn) in the litter are shown in Table 3. Some tree species indicate high quantities of heavy metals in the litter horizon. It may be because every tree species is characterized by different filtration property. Some species show a tendency to intake some heavy metals, which also have ability to accumulate to a major or a minor extend.

Table 2. Mean magnetic susceptibility values along topsoil profiles

Depth [cm]	Magnetic susceptibility along profiles [x 10^{-5} SI]		Field magnetic susceptibility on surface [x 10^{-5} SI]	
	Coniferous trees	Deciduous trees	Coniferous trees	Deciduous trees
0–1	9.65	18.56	8.82	13.88
2–5	25.64	23.97	-	-
6–10	23.17	16.81	-	-
11–15	22.88	12.88	-	-
16–20	24.87	14.62	-	-
21–25	28.15	14.24	-	-
26–29	24.69	12.04	-	-

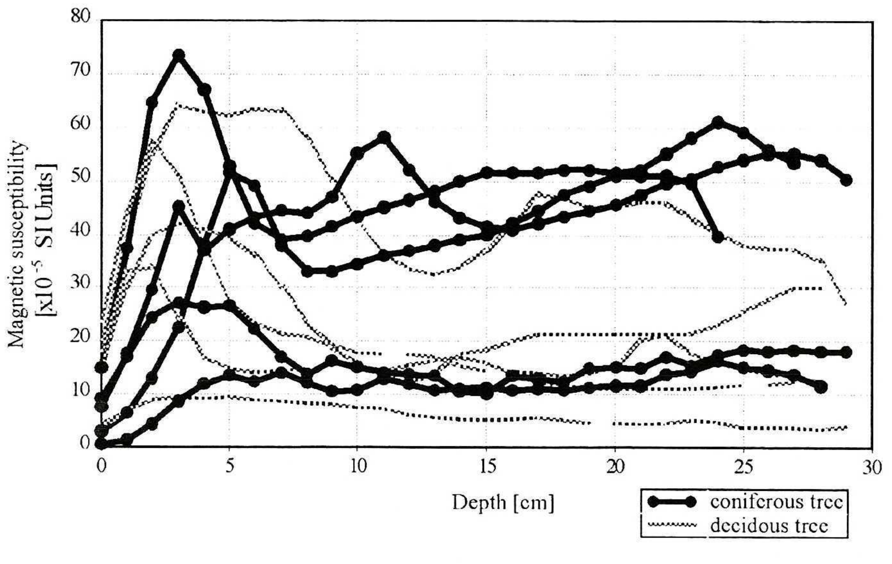

Figure 1. Distribution of magnetic susceptibility along soil profiles

Heinrichs and Mayer [6] investigated two forest ecosystems (beech and spruce forest) and made similar observations.

In comparison to the other elements, there is a considerably higher amount of Mn in all samples. This may depend on the bedrock and could not have been caused by anthropogenic pollution because of the lack of correlation between Mn, Zn and Cd content [4]. Significant differences in the content of some elements under different tree species were observed. Generally the content of Fe, Cu and Pb is higher for the coniferous tree stands (especially for spruce, Douglas fir and fir). No significant difference in

Table 3. The values of the specific magnetic susceptibility and heavy metal contamination of the litter samples

Species	χ	Pb	Cu	Fe	Cd	Mn	Zn
	$*10^{-8}[m^3kg^{-1}]$	mg/kg					
Spruce	48.7	37.3	15.3	1362.5	0.4	2781.3	70.0
Douglas fir	38.7	40.3	13.5	1522.5	0.6	3775.0	82.5
Fir	20.2	23.5	6.0	2280.0	0.2	3325.0	235.0
Blue spruce	7.0	6.8	4.5	410.0	0.2	2100.0	60.0
Pine	4.9	6.3	6.8	330.0	0.4	1731.3	62.5
Red oak	22.6	30.0	5.0	522.5	0.9	3887.5	125.0
Beech	18.4	11.5	7.8	780.0	0.2	2975.0	55.0
Hornbeam	7.1	6.5	8.3	517.5	0.1	4862.5	37.5
Common oak	5.0	4.3	5.0	200.0	0.1	2100.0	25.0
Birch	3.1	3.8	6.0	195.0	0.7	2787.5	232.5

χ - specific magnetic susceptibility

Mn, Zn and Cd contents between coniferous and deciduous trees was observed. Similar results concerning the Cd, Cu, Pb and Zn distribution in soil and vegetation were reported by Alriksson and Eriksson [1] from Sweden. In comparison with the data in this study, they found a similar amount of Cd and Cu, higher quantities of Zn and lower amounts of Pb in the litter horizon under different tree species to those reported here.

The amount of some heavy metals corresponds to a specific magnetic susceptibility value. Positive correlation coefficients between χ and heavy metals (Pb, Cu, Cr, Co) in the litter were also observed (Tab. 4).

Table 4. Correlation coefficients between magnetic susceptibility and heavy metal contents in the litter samples

χ	Pb	Cu	Fe	Cd	Mn	Zn
All samples	0.945	0.851	0.675	0.358	0.350	0.008
Coniferous forest	0.960	0.941	0.549	0.577	0.678	-0.020
Deciduous forest	0.890	-0.036	0.758	0.352	0.256	-0.130

CONCLUSIONS

Tree-species-related changes in magnetic susceptibility were observed in the soil of Pruhonice Park. Generally, with the exception of the uppermost layer, the mean value of magnetic susceptibility (κ) along soil profiles is higher for coniferous than for deciduous forests. The type of forest stand may, therefore, influence the specific magnetic susceptibility and heavy metal content in the litter horizon as well. Further studies are needed to better identify the cause of vegetation impact on the magnetic susceptibility.

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