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Profile distribution of metals in Gelic Cambisols of Kaffiöyra, Spitsbergen

ABSTRACT: Distribution of the following elements: Na, K, Ca and Mg, and heavy metals: Fe, Mn, Zn, Cu, Ni, Co, Pb and Cd was analysed in the Gelic Cambisols profile from Kaffiöyra, Spitsbergen. The leaching of Ca, Fe, Mn, Co and Cu, and in a less degree Mg and Ni downward the profiles occurs in the studied soil due to pedogenic processes. The surface soil horizon is strongly enriched in Na and K of marine origin and Pb and Cd from anthropogenic pollution of the distant atmospheric transports.

Key words: Arctic, Spitsbergen, Gelic Cambisols, metal elements.

Introduction

Studies of the factor influencing the profile distribution of metals is relatively difficult in tundra soils. The difficulties are caused by simultaneously running of the pedologic and cryogenic processes in the soil. Cryogenic processes, especially in Gelic Gleysols, a prevailing soil unit in the tundra regions, cause in a profile the blurring of the morphogenic features and chemical composition differences, which developed due to pedogenic processes. Even mature Gelic Gleysols occuring in the climax tundra plant communities, frequently display weakly development genetic horizons or their complete absence (Karavaeva 1974). According to Tedrow and Cantlon (1958), soils with distinctly developed profile form in the Arctic region only from well-drained sediments, where cryogenic phenomena display lesser role. In the present study the profile metal contents distribution as a result of pedogenic processes in Gelic Cambisols formed from sands and gravels were investigated.

Investigation area and soil material

Soil studies have been performed at the maritime lowland of Kaffiöyra at the western seaside of Spitsbergen (see: Plichta and Kuczyńska 1991, Fig. 1). A general characteristics of the geographic environment of this area has been outlined in the work of Plichta and Kuczyńska (1990). The investigate soil belong to Gelic Cambisols, according to the FAO-UNESCO classification (1974). In the Tedrow's (1973) classification, the frequently used for Arctic zone, the soils fall in the division of the Arctic Brown soils of the subpolar deserts.

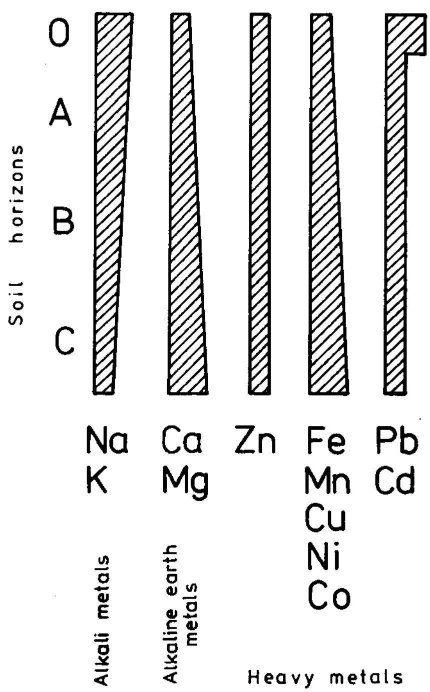

Fig. 1. Schematic diagrams of the element distribution in the Gelic Cambisols profile

Gelic Cambisols occurs mostly on old, isostatically raised shore accumulation areas formed from coarse textured sediments in well-drained sites. Lichen tundra, dry moss tundra and deflation tundra are the typical plant communities of the Gelic Cambisols (Gugnacka-Fiedor and Noryśkiewicz 1982).

Gelic Cambisols have well developed profile with full differentiation into genetic horizon. The organic horizon O consists mainly of weakly decomposed lichens, mosses and algae (Plichta and Luścińska 1988). Its thickness equals 1—2 cm. The grayish brown (10YR 3/2) humic horizon Ah has thickness 8—15 cm. The underlying dark brown (10 YR 4/3) cambic horizon B has widely variable thickness from 20 to 40 cm. The parent rock C usually contain a significant amount of $CaCo_3$ transported from the upper horizons. More important features of the studied soil are presented in the Table 1.

Samples for analyses have been collected from eight soil profiles. Contents of the following metals: Na, K, Ca, Mg, Fe, Mn, Zn, Cu, Co, Ni, Pb and Cd, have been determined in air-dry samples (< 1 mm) after its dissolution in the mixture of concentrated nitric, sulfuric and perchloric acids. Individual elements have been determined by the method of the atomic absorption spektrophotometry.

Table 1

Some properties of Gelic Cambisols

Horizon		Profile							
		1	2	3	4	5	6	7	8
C %	O	9.05	7.93	6.84	8.87	10.00	9.96	—	—
	Ah	0.53	2.42	1.46	0.72	0.85	2.09	1.29	0.53
	B	0.34	0.60	0.78	0.24	0.37	0.75	0.45	0.60
	C	0.17	0.31	0.29	0.15	0.19	—	0.28	0.07
N_t %	O	0.554	0.563	0.375	0.334	0.466	0.490	—	—
	Ah	0.039	0.190	0.104	0.070	0.077	0.187	0.106	0.058
C/N	O	16.3	14.1	18.2	26.6	21.5	16.2	—	—
	Ah	13.6	12.7	14.0	10.3	11.0	11.2	12.2	9.1
P %	Ah	0.077	0.091	0.087	0.043	0.060	0.061	0.069	0.053
	B	0.083	0.074	0.096	0.046	0.059	0.067	0.055	0.044
C/P	Ah	6.9	26.6	16.8	16.7	14.2	34.3	18.7	10.0
	B	4.1	8.1	8.1	5.2	6.3	11.2	8.2	13.6
$CaCO_3$ %	Ah	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
	B	0.6	0.0	0.0	0.0	0.0	0.0	0.3	1.5
	C	13.6	0.0	0.0	7.6	11.5	—	0.3	2.6
pH_{H_2O}	O	6.0	5.6	6.5	4.8	5.7	6.4	—	—
	Ah	6.8	5.3	6.4	5.4	7.8	6.7	7.1	6.9
	B	7.8	6.1	6.3	6.7	7.9	7.4	7.0	8.5
	C	8.1	7.3	—	—	8.0	—	7.5	8.4
CEC $\frac{me}{100\ g}$	Ah	1.7	11.9	5.9	1.1	1.9	5.8	5.7	1.6
	B	2.8	2.8	1.4	1.1	0.9	0.8	1.0	3.3
	C	6.7	1.1	0.7	0.7	6.6	—	0.8	0.4
Grain separate $<20\mu m$	Ah	5	12	7	3	2	7	8	6
	B	12	12	8	4	7	4	6	9
	C	11	9	4	5	14	—	6	3

Results and conclusions

The determined metals distribution in the studied Gelic Cambisols profile is shown in the Table 2 and Figure 1.

Table 2

Chemical composition of Galic Cambisols

Element	Horizon	Content ranges	Average value	Standard deviation	Content in a horizon versus content in the parent rock
Na %	O	0.03—0.42	0.15	0.16	1.67
	Ah	0.08—0.20	0.12	0.05	1.33
	B	0.09—0.14	0.12	0.02	1.33
	C	0.05—0.11	0.09	0.02	1.00
K %	O	0.55—2.25	1.43	0.56	1.70
	Ah	0.53—2.05	0.97	0.57	1.15
	B	0.48—1.52	0.80	0.36	0.95
	C	0.46—1.84	0.84	0.51	1.00
Ca %	O	0.18—0.90	0.53	0.25	0.18
	Ah	0.10—2.83	0.60	0.95	0.21
	B	0.08—3.26	0.83	1.06	0.28
	C	0.34—5.65	2.92	1.86	1.00
Mg %	O	0.44—0.92	0.79	0.18	0.83
	Ah	0.51—1.35	0.69	0.28	0.72
	B	0.48—1.29	0.75	0.26	0.78
	C	0.50—1.94	0.96	0.49	1.00
Fe %	O	1.28—3.03	2.21	0.56	0.65
	Ah	2.04—5.14	3.14	0.92	0.92
	B	1.85—5.17	3.24	1.16	0.95
	C	1.78—6.18	3.41	1.55	1.00
Mn ppm	O	97—552	272	160	0.60
	Ah	194—635	375	149	0.82
	B	228—645	427	134	0.94
	C	326—679	456	128	1.00
Zn ppm	O	46— 99	77	19	0.99
	Ah	38—152	82	33	1,05
	B	39—106	75	20	0.96
	C	52—105	78	20	1.00
Cu ppm	O	7.3—22.4	16.2	5.4	0.58
	Ah	4.4—54.9	23.7	15.1	0.86
	B	5.6—75.0	28.0	20.7	1.01
	C	9.9—43.7	27.7	13.4	1.00
Co ppm	O	2.5—9.0	5.9	2.7	0.63
	Ah	5.0—13.0	7.9	3.4	0.84
	B	3.4—20.4	8.9	5.2	0.95
	C	3.3—19.9	9.4	5.6	1.00

Ni ppm	O Ah B C	12.3—23.0 15.3—32.8 13.7—38.9 13.6—41.8	20.3 25.1 24.9 25.6	4.1 6.8 8.6 10.9	0.79 0.98 0.97 1.00
Pb ppm	O Ah B C	13.1—20.0 7.2—21.9 6.5—25.3 8.5—24.4	16.1 11.8 12.7 12.4	3.1 4.6 6.0 5.6	1.30 0.95 1.02 1.00
Cd ppm	O Ah B C	0.09—0.40 0.05—0.21 0.05—0.19 0.09—0.21	0.24 0.13 0.15 0.15	0.11 0.05 0.04 0.05	1.60 0.87 1.00 1.00

The surface horizons of Gelic Cambisols are strongly enriched in sodium and potassum. The concentration ratio of both Na i K in the organic horizon O to the parent rock equals 1.7. On the other hand, the studied soils are distinctly low in Ca. The migration coefficient of calcium with respect to the parent rock equals 0.18 for the horizon O and 0.28 for the horizon B. Relatively weak displacement downward the profile is shown by magnesium.

The tendency of the content to increase downward the profile is typical of iron, magnese, copper and cobalt. Especially low concentrations of these elements have been found in the organic horizon O and the humic horizon Ah. There the ratio of this metals concentrations to their concentrations in parent rock equal about 0.6. The presented migration coefficients of the metals are somewhat overstated, because of the calcium carbonate removal from the surface horizons and its accumulation in the parent rock (Table 1), leading thus to relative element content decrease in the latter.

The horion O displays significantly higher lead and cadmium contents than the parent rock. The concentration coefficient of this horizon equals 1.30 for lead and 1.60 for cadmium.

Element distribution in the Gelic Cambisols profile is connected mainly with pedogenic processes and it is typical of the leaching type of the water circulation regime. The climate humidity index suggests the descending water movement in the soil. This index being the ratio of the total annual precipitation to the potential evaporation equals 2.86*. It is a value characteristic for a humid climate (Ivanov 1958, vide Bednarek and Prusinkiewicz 1980).

The cryogenic processes in Gelic Cambisols do not display any important role (Bockheim 1980). The morphological features connected with cryoturbation processes have not been observed in the soil profile. Also the element migration in the profile does not seem to be affected by cryogenic processes in any significant degree due to a low soil humidity (Globus 1987) and low content of fine grain separates (Table 1).

* The climate humidity index was calculated on the basis of the data from Isfjord Radio (Steffenson 1982).

Thus, the chemical composition of Gelic Cambisols at Kaffiöyra is first of all influenced by pedogenic processes leading to the pH decrease and leaching of such heavy metals as Fe, Mn, Co and Ni. The metal leaching is also facilitated by low clay content, humus presence and low pH (Alekseev 1987). In the investigated soil samples the pH_{H_2O} value falls in the ranges 4.8 to 6.5 for the organic and humic horizons.

A weak biological elements accumulation, resulting from a low primary production and shallow soil penetration by plant roots (Aleksandrova 1969; Dennis 1977) stimulates also a distinct differentiation of the chemical composition of the Gelic Cambisols. Absence of the biological circulation of elements from the deeper soil layer causes that the leaching process effects are not blurred.

In connection with low importance of the biological element accumulation in the surface soil part, the high lead and cadmium concentrations in the organic horizon O suggest their origin from anthropogenic pollution of the distant atmospheric transport. This yield the conclusion, which is not a new, that the atmospheric pollution has presently a world-wide extent (Kabata-Pendias and Pendias 1979).

A significant enrichment of the surface soil horizons in sodium and potassium derived from seawater aerosol emitted during storms is a common phenomenon in maritime zones (Marks 1978; Bockheim 1980; Cambell and Claridge 1987). Certain amoung of magnesium come from the same source, causing that the content of this relatively easily leachable element is remarkable in the surface soil horizons when compared with their in parent rock.

The performed analyses indicate a significant intensity of the pedogenic processes yielding chemical composition gradients in the Gelic Cambisols profiles of the Arctic tundra at Kaffiöyra. However, Tedrow and Thompson (1969) have found small differences in the chemical composition of the two Arctic Brown soil (i.e. Gelic Cambisols) profiles located in Northern Alaska and Prince Patrick Island. Small number of publications on the element composition, especially on heavy metals, makes impossible a more unambiguous determination of the element differentation intensity in the Gelic Cambisols profile in the Arctic zone.

The performed studies yielded the following conclusions. The chemical composition differentiation of the Arctic tundra Gelic Cambisols at Kaffiöyra is determined by pedogenic processes, element inflow from the seawater aerosol and pollution of the anthropogenic origin. Pedogenic processes cause mostly the leaching of Ca, Fe, Mn, Cu and Co, and in a less degree Ni and Mg downward the soil profile. The organic horizon O and the humic horizon Ah have most reduced concentrations of these elements. Also these horizons are most enriched in Na and K. Significant amounts of Na and partly K have their source in the seawater aerosol. Appreciable concentrations of lead and cadmium in the organic horizon O are probably connected with atmosferic pollution.

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Streszczenie

Badania nad profilowym zróżnicowaniem metali przeprowadzono w Gelic Cambisols niziny nadmorskiej Kaffiöyra, Spitsbergen. Przeanalizowano łącznie 8 profili glebowych. Wyniki podstawowych właściwości chemicznych i fizycznych Gelic Cambisols przedstawiono w tab. 1. Zróżnicowanie profilowe zawartości Na, K, Ca and Mg oraz metali ciężkich Fe, Mn, Zn, Cu, Co, Ni, Pb i Cd ilustruje tab. 2 i fig. 1.

Procesy pedogeniczne w Gelic Cambisols prowadzą do wymywania w głąb profilu glebowego Ca, Fe, Mn, Co i Cu, w mniejszym stopniu Ni i Mg. Silnie wzbogacone są poziomy organiczne O i próchniczne Ah w Na i K. Duża zawartość Na związana jest z dopływem aerozolu morskiego. Stosunkowo znaczna zawartość Pb i Cd w poziomie organicznym pochodzi prawdopodobnie z zanieczyszczeń dalekiego transportu atmosferycznego.

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