Multielement-analysis of a montane beech forest in Hungary

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Synopsis

By increasing elevation, the quantity of some heavy metals, presumably of anthropogenic origin, increases in the uppermost litter layer (A_{00}) of the soils of the Mátra mountains.

In montane beech forests (Aconito-Fagetum) the litter of *Acer pseudoplatanus* is rich, whereas that of *Fagus sylvatica* is poor in nutrients.

Heavy metals deposited from the air or leached from the foliage of trees are accumulated by organisms of the ground layer (mosses, mushrooms). The concentration factor of As and Cd in the investigated moss and mushroom species, when correlated with the heavy metal content of the litter, may amount to 35–40.

Multi-element analysis, montane beech forest, heavy metals, tree layer, shrub layer, field layer, ground layer, litter

Introduction

The so-called multi-element analysis is a new field of vegetation research, investigating the chemical element composition of the components of plant communities as well as their soils. By means of basic data it is possible to determine, which elements of the components are of geogenic origin, and which derive from atmogenic immissions.

Within the scope of the International Geosphere-Biosphere Program the element concentration cadastres of several zonal and characteristic plant communities of Hungary have been completed. In this paper the results of investigations carried out in a montane beech forest are presented.

Sampling site

Geographical potentials of Hungary restrict characteristic montane beech forests onto peaks above 900 m as well as northern slopes of the Northern Central Mountains of the country. This plant community occurs also in the Mátra mountains (on peaks Piszkéstetô, Galyatetô and Kékes, comp. with KOVÁCS 1975). On peak Galyatetô, components of the tree layer of the montane beech forest are *Fagus sylvatica* (as dominant species), *Acer pseudoplatanus*, *Acer platanoides* and *Ulmus glabra*. In the shrub layer, besides *Fagus sylvatica* and several *Acer* species, characteristic are *Fraxinus excelsior*, *Sorbus aucuparia*, *Rosa pendulina*, *Rubus idaeus* and *Ulmus glabra*. In the field layer *Galium odoratum* and *Mercurialis perennis* are often dominant species. Characteristic elements of the community are *Lunaria rediviva*, *Prenanthes purpurea*, *Salvia glutinosa*, *Polygonatum verticillatum*, *Senecio nemorensis subsp. fuchsii*, etc. Most species of the community belong to the floristic elements of the higher groupings of associations like Fagetalia, Carpino-Fagetea and Querco-Fagetea. The community can be considered as a vicar for the Central European Abieto-Fagetum in the Hungarian Central Mountains.

Methods of sampling

Samples were taken according to the prescriptions of multi-element analysis investigations (LIETH & MARKERT 1988). Soil was sampled in every 10 cm layer down to 1 m depth.

The chemical element composition of the following species was determined:

Tree layer: *Fagus sylvatica*, *Acer pseudoplatanus*; twig and leaf samples were taken from 10 layers of the crowns of 10 individuals each.

Shrub layer: *Acer platanoides*, *A. pseudoplatanus*, *Fagus sylvatica*, *Fraxinus excelsior*, *Rosa pendulina*, *Rubus idaeus*, *Sorbus aucuparia*, *Ulmus glabra*.

Field layer: *Galium odoratum*, *Aegopodium podagraria*, *Campanula trachelium*, *Festuca gigantea*, *Hordelymus europaeus*, *Lunaria rediviva*, *Mercurialis perennis*, *Milium effusum*, *Polygonatum verticillatum*, *Prenanthes purpurea*, *Salvia glutinosa*, *Senecio nemorensis subsp. fuchsii.*

In every case 10 individuals of the populations were sampled. Element contents were determined in different organs – root, stem, foliage, flower or inflorescence – of the plants, respectively.

In the ground layer mosses (*Dicranella heteromalla*, *Ditrichum pusillum var. tortile*, *Bartramia pomiformis*, *Hypnum cupressiforme*) and mushrooms (*Clitocybe gibba*, *Collybia confluens*, *C. peronata*, *Ganoderma applanata*, *Mycena pura*, *M. pelianthina* and *Pluteus atricapillus*) were sampled for analysis. In the plant and soil samples the following chemical

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elements were detected with an ICP-AES: Al, As, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, Ga, K, Li, Mg, Mn, Na, Ni, P, Pb, Se, Si, Sr, Ti, V and Zn. Nitrogen was determined after Kjeldahl.

Element content of the soil

Characteristic soil type of the investigated Aconito-Fagetum community is brown earth. The pH-value of the uppermost 20 cm layer, rich in organic material, is 4.7 when measured in water, and 3.9 when measured in KCl. Al, Ca, Mg, K and P, as well as some heavy metals, like Mn, Fe, Zn, V, Cr, Co, Cu, Cd, Pb and Ni are detectable in the highest amounts in this layer. The total amount of the measured elements in the soil is 50,138 µg g^{-1}, of which heavy metals amount to 24,800 µg g^{-1}.

Soil investigations carried out in the 1960s show that pH-values measured in a soil profile at Galyatetô used to be 5.4–5.6 when measured in water, and 4.2–4.5 when measured in 1n KCl. In the last 25–30 years an acidification of different soil types in the Mátra mountains has occurred (KOVÁCS et al. 1990). It seems that the element content of the uppermost soil layer is strongly influenced by the litter of *Acer pseudoplatanus*, rich in chemical elements.

A comparison of data from soil profiles at different elevations in the Mátra mountains shows an increase of heavy metal (Co, Cr, Cu, Fe, Mn, Pb and Zn) contents with increasing elevations (Table 1.). The same phenomenon was indicated by several other authors in Europe (e.g. KORFF et al. 1980, SCHRIMPFF 1980, GODT & LUNKENBEIN 1983, KUES 1984, GODT 1985, SCHULTZ 1985, 1986, – all cited in GLAVAC 1986 and/or in WITTIG 1991). Heavy metals, deposited onto the foliage are leached into the soil by precipitation, where they get absorbed (WITTIG 1991).

Tab. 1
Heavy metal content of the soil litter layer (in µg g^{-1} dry weight) at different elevations in the Mátra mountains

	1	2	3
Cd	0.8	3.0	2.1
Co	12.1	14.4	32.1
Cr	6.3	9.5	14.4
Cu	8.3	8.7	12.8
Fe	16835	15190	21767
Mn	1147	1407	2870
Ni	6.1	8.0	6.4
Pb	23.9	26.9	44.0
Zn	45.9	49.8	55.6

1. **Quercetum petraeae-cerris community on lessivated brown forest soil between Mátrafüred and Mátraháza, at an elevation of 520 m.**
2. **Querco-Carpinetum community on lessivated brown forest soil near Mátraháza at an elevation of 710 m.**
3. **Aconito-Fagetum community on brown earth on peak Galyatetô at an elevation of 900 m.**

Tab. 2.
Chemical element content (in µg g^{-1} dry weight) of leaves and twigs of Acer pseudoplatanus and Fagus sylvatica in the investigated Aconito-Fagetum community on peak Galyatetô (values are the means of 10 samples each taken from 10 layers of the crowns)

	Acer pseudoplatanus		Fagus sylvatica	
	leaf	twig	leaf	twig
Al	64.9	52.6	75.2	72.9
As	<d.l.*	<d.l.	<d.l.	<d.l.
B	34.2	19.9	17.0	16.2
Ba	30.9	52.2	14.5	32.5
Ca	13401	13278	8120	9857
Cd	0.09	0.26	0.3	0.28
Co	<d.l.	0.07	0.01	0.01
Cr	<d.l.	<d.l.	<d.l.	<d.l.
Cu	7.2	5.6	6.4	7.2
Fe	136	121	145	176
Ga	0.06	0.19	0.3	0.06
K	12347	3614	7189	1976
Li	3.2	2.9	2.1	2.2
Mg	1948	792	1281	520
Mn	206	140	192	82
Mo	0.2	0.2	0.5	0.5
Na	114	118	218	142
Ni	2.9	2.9	1.1	1.7
P	1664	871	1191	550
Pb	0.3	9.2	2.1	20.0
Se	0.07	<d.l.	<d.l.	<d.l.
Si	96.8	93.3	201	89.4
Sr	50.9	94.3	23.1	51.2
Ti	1.1	1.3	1.9	2.9
V	0.07	0.28	0.09	0.5
Zn	46.3	34.6	32.4	34.6

*<d.l.: values under the detection limit

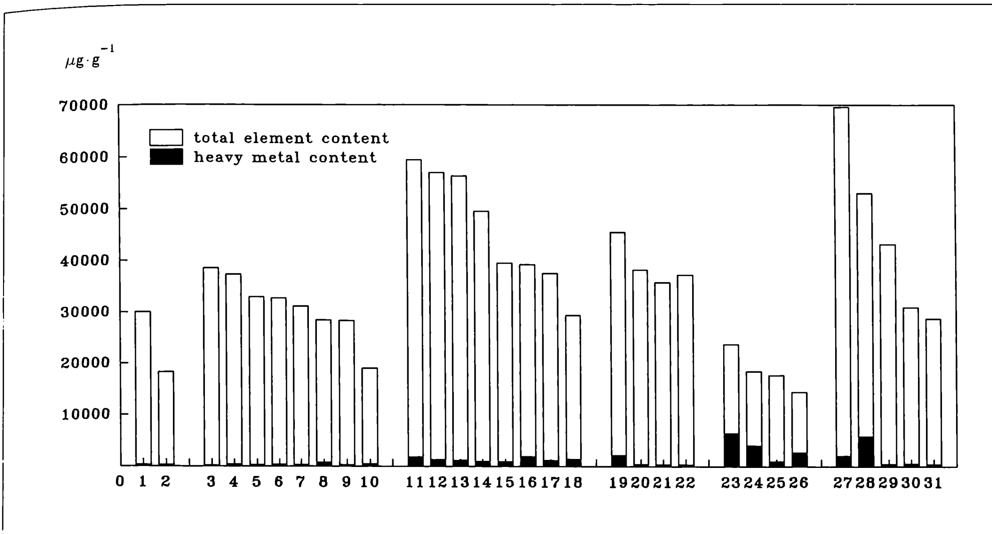

Fig. 1

Total element and heavy metal content of plant and mushroom species in an Aconito-Fagetum plant community on peak Galyatetô, Hungary

List of species

Tree layer: 1. Acer pseudoplatanus, 2. Fagus sylvatica;
shrub layer: 3. Fraxinus excelsior, 4. Ulmus glabra, 5. Rubus idaeus, 6. Sorbus aucuparia, 7. Acer pseudoplatanus, 8. A. platanoides, 9. Rosa pendulina,10. Fagus sylvatica;
field layer, dicotyledones: 11. Salvia glutinosa, 12. Aegopodium podagraria, 13. Mercurialis perennis, 14. Senecio nemorensis subsp. fuchsii, 15. Campanula trachelium, 16. Galium odoratum, 17. Prenanthes purpurea, 18. Lunaria rediviva;
field layer, monocotyledones: 19. Polygonatum verticillatum, 20. Milium effusum, 21. Hordelymus europaeus, 22. Festuca gigantea;
ground layer, mosses: 23. Bartramia pomiformis, 24. Ditrichum pusillum var. tortile, 25. Hypnum cupressiforme, 26. Dicranella heteromalla;
ground layer, mushrooms: 27. Mycena pelianthina, 28. M. pura, 29. Clitocybe gibba, 30. Collybia confluens, 31. C. peronata

Element content of trees

The leaves of *Acer pseudoplatanus* contain 1.6 times more, whereas the twigs of the same species contain 1.4 times more elements than the same organs of *Fagus sylvatica*. The difference is greatest in the case of macroelements, like Ca, K, Mg and P (Table 2.). The leaves of *Acer pseudoplatanus* contain higher amounts of Sr as well (Ca, Mg and Sr are generally accumulating corresponding). B and Ba occur also in higher quantities in the leaves of *Acer pseudoplatanus*, whereas the leaves of *Fagus sylvatica* contain more Si. Total measured element content (element pool) of the leaves of *Fagus sylvatica* in the submontane beech stand is 21,824 μg g^{-1}.

Total N content is 2.8% m/m in the leaves of *Acer platanoides*, and 2.6% m/m in the leaves of *Fagus sylvatica*. Investigations carried out in different beech stands of the Mátra mountains show that *Fagus sylvatica* contains less elements than other tree species. In addition to the effect of bedrock this might also play a role in the formation of acidophilic beech forests. On the other side, a higher element content of the foliage of *Acer pseudoplatanus* might also contribute to the formation of richer shrub and field layers in montane beech forests.

Element content of shrubs

Species of the shrub layer also play a significant role in the biogeochemical cycle of the investigated beech forest. Rich in the investigated elements are *Fraxinus excelsior*, *Ulmus glabra*, *Rubus idaeus*, *Acer pseudoplatanus*, *A. platanoides* and *Rosa pendulina*. In the foliage of *Fagus sylvatica* individuals constituting the shrub layer, the amount of elements is less than in the leaves of other shrub layer species (Fig. 1.). The Ca and the Mg content of beech leaves is remarkably low. In the leaves of some shrub layer species some rarely detectable elements – like As in *Acer platanoides* and Se in *Rubus idaeus* as well as *Acer platanoides* – are also present in detectable amounts.

N content in the leaves of the investigated shrubs is as follows: *Rubus idaeus*: 3.8% m/m *Fraxinus excelsior*: 3.3% m/m *Sorbus aucuparia*: 2.8% m/m *Acer platanoides* and *Acer pseudoplatanus*: 2.6% m/m *Fagus sylvatica*: 2.4% m/m *Rosa pendulina*:

1.9% m/m. *Rubus idaeus* is a nitrophilous plant species. It appears after clear-cutting of montane and submontane beech forests.

Element content of field layer species

Species of the field layer have a higher element pool, than those of the tree or shrub layers (Fig. 1.). The nutrient-rich uppermost layer of brown earth is favourable for the formation of a species-rich field layer. Some species, like *Salvia glutinosa*, *Aegopodium podagraria* and *Mercurialis perennis* have relatively high nutrient pool. In addition, in *Salvia glutinosa* and *Galium odoratum* relatively high amounts of heavy metals (first of all Fe) were detectable. Selenium, a rather rare element in plants was detected in the stems of *Galium odoratum*, *Senecio nemorensis subsp. fuchsii* and *Festuca gigantea*, as well as in the inflorescence of *Lunaria rediviva*. Arsenic was detectable in the stem of *Galium odoratum*.

Some elements occur in some plant species or in some organs of these species – depending on their specific features – in relatively high amounts. Several elements are present in high quantities in the roots of *Milium effusum*. The roots of *Senecio nemorensis subsp. fuchsii* contained 3.9 $\mu g\ g^{-1}$ Cd, whereas in the stems of the same species 5.31 $\mu g\ g^{-1}$, and in the leaves 1.5 $\mu g\ g^{-1}$ Cd was detected. These species might be considered as potential accumulation indicators of the mentioned elements. First of all in the roots of *Galium odoratum* and *Mercurialis perennis*, which constitute facies in montane and submontane beech forests, relatively high amounts of Cd, Cu and Pb were detected. On the basis of his investigations WITTIG (1991) found, that *Mercurialis perennis* accumulates Cd, Cu, Pb and Zn. Thus, this species can be considered as an accumulation indicator of heavy metals (comp. with LUWE et al. 1990, NEITE et al. 1991). The root systems of *Festuca gigantea*, *Hordelymus europaeus* and *Milium effusum*, creating extensive networks in the soil, accumulate significant amounts of Al, Co, Fe, Ga, Li, Mn, Pb, Ti, V and Zn.

The organs of *Mercurialis perennis*, occurring on andesite base rock in the Mátra mountains, contain higher amounts of Zn, than those collected on limestone in the Bükk mountains. Similarly, in the organs of *Galium odoratum* grown on andesite higher amounts of Zn were detectable. Even in the Bükk mountains the organs of *Mercurialis perennis* contained more Zn, when compared with the organs of other species.

A good nitrification dynamics in brown earth is indicated by the relatively high N content of several field layer species (e.g. 4.0% m/m in *Mercurialis perennis* and *Senecio nemorensis subsp. fuchsii*, and 5.1% m/m in *Lunaria rediviva*).

Element content of mosses

Heavy metals getting onto the Earth's surface as wet or dry depositions are accumulated by mosses. As a consequence of their position in communities, as well as the way of their water and nutrient uptake, mosses contain more heavy metals than field layer species. In addition to Fe, their Cu and Zn content is also significant. In some mosses, when compared with herbaceous plants, a higher accumulation of Cr, Ni, Pb and V can be established. In *Bartramia pomiformis* and *Ditrichum pusillum* var. *tortile* Cr, Ni, Pb, V and Zn were present in high quantities.

It seems that the ground layer (including mushrooms as well) is the place in the Aconito-Fagetum community, where most heavy metals are accumulated. Mosses present in this layer are accumulating significant amounts of heavy metals. However, heavy metal content of the species of this layer is rather different. Those species, which contain high amounts of heavy metals (e.g. *Bartramia pomiformis*, *Ditrichum pusillum* var. *tortile*), accumulate more Al as well. The N content of mosses is between 2.4 and 2.7% m/m.

Element content of mushrooms

Mushrooms own a peculiar way of nutrient uptake. Their mycelia, forming a network in the litter, take up not only water and nutrients, but also heavy metals. Saprophytic mushrooms, like *Mycena pelianthina* have a conspicuously high chemical element pool (including heavy metals). *Mycena pura* contains high amounts of Fe.

The substrate of mushrooms contains 1.3 $\mu g\ g^{-1}$ Cd on an average. First of all *Collybia confluens*, *C. peronata* and the two *Mycena* species accumulated this element in extraordinarily high amounts (Table 3.). In the cap of *Collybia confluens* the concentration factor (element content of mushroom in $\mu g\ g^{-1}$/ element content of litter in $\mu g\ g^{-1}$) was 42.2. It seems that Cd is subject to accumulation in several mushroom species (LAAKSOVIRTA and ALAKUIJALA 1978, KUUSI et al. 1981, LODENIUS et al. 1981, PROBST and SCHMIDT 1986, TYLER 1982, GAST et al. 1988, KOJO and LODENIUS 1989).

With the exception of *Mycena pura* arsenic was found in all mushroom species, although in the litter layer this element was not detectable. First of all *Mycena pelianthina* contained markedly high amounts of As (33.8 – 36.5 $\mu g\ g^{-1}$). An accumulation of As is characteristic of some mushroom species (STIJVE and BOURQUI 1991).

The caps of the investigated *Collybia* species contained 1.2–1.9 $\mu g\ g^{-1}$ Se as well.

Tab. 3
Arsenic and cadmium content of litter and saprophytic mushrooms (in µg g[-1] dry weight) in investigated Aconito-Fagetum community on peak Galyatetô

Sample	As content	Cd content
Litter (n=5)	<d.l.*	1.2
Clitocybe gibba, stipe	9	1.9
Clitocybe gibba, cap	12.2	2.2
Collybia confluens, stipe	0.27	32.4
Collybia confluens, cap	3.5	50.7
Collybia peronata, stipe	1.5	11.1
Collybia peronata, cap	11.8	28
Mycena pelianthina, stipe	36.5	48.9
Mycena pelianthina, cap	33.8	46
Mycena pura, fruit body	<d.l.	25.1

*<d.l.: values under the detection limit

Summary

The element content of the uppermost layer of the soil of a montane beech forest (Aconito-Fagetum) is greatly influenced by the chemical composition of the species of the tree, shrub and field layers.

The relatively high heavy metal content of the litter layer is caused by the deposition of heavy metals of anthropogenic origin onto the foliage of trees, and their subsequent leaching onto the soil surface.

In beech forests the different element content of the crowns of *Acer pseudoplatanus* and *Fagus sylvatica* result in the formation of litter patches, differing in their alkaline and alkaline earth metal contents.

In the field layer species of high element content are dominating. Some species or organs of species contain some elements in high quantities.

In the investigated montane beech forest heavy metals are accumulated first of all in the moss and mushroom species, constituting the ground layer of the forest. These species own a peculiar way of element uptake. The concentration factor of some heavy metals in the mushrooms, correlated with the heavy metal content of the litter may even amount to 40.

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