THE RELATIONSHIPS BETWEEN SOIL CHEMISTRY AND THE HEAVY METAL CONTENT OF VEGETATION ON KARSTS

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Summary
The soil-vegetation system is of great importance to processes in the karst geo-ecological system. Soils can buffer those environmental impacts that change the karst system. Within certain limits, soils can bind the non-karstic materials (e.g. heavy metals) which enter the soil by deposition or by land utilisation. Acidification of soil can result in entry of heavy metals to vegetation via water. The present paper describes investigations in the dolines of the Bükk and Aggtelek regions, Hungary. The heavy metal contents of soil and vegetation on slopes vary with distance from the transportation routes. The heavy metal intake of plants is more significant on slopes nearer the transportation routes and in pinewoods on acid soils.

Introduction

The soil-vegetation system of karst regions is important from the viewpoint of the processes in the sensitive karst geo-ecological system. Soils can buffer those environmental impacts which change the processes of the karst system. Within certain limits, soils can buffer the different damaging materials (e.g. heavy metals) which get into the soil by different depositions or by land use. Through the acidification of soil, heavy metals in water may be taken up by vegetation and can have toxic impacts for the plants. The present study investigates the heavy metal content of plants in relation to the soil chemistry in two dolines in areas of the Bükk and Aggtelek regions that are ecologically different.

Methods

Soil and plants samples were collected in the E-W and N-S sections of dolines. The plant samples were collected from 1x1 m quadrates (without selection), and were air-dried. Soil samples were analysed in the laboratory for pH value (digital pH meter), and the heavy metal content both of soils and plants were measured on a Perkin-Elmer ASS.

Discussion

In an earlier investigation we showed that the heavy metal content is higher in the karst soils than could be derived from the parent rock alone (*Bárány-Kevei, 1998*), the excess being from dry and wet deposition. These acid precipitation's cause soil-acidification. In general heavy metals do not accumulate in acidic soils but are transported into plants by uptake of soil moisture. This means that the mobility of heavy metal depends on the soil pH. *Brümmer et al.* (1991) established that the metal mobility related to pH value is Cd pH < 6.0-6.5; Mn < 5.5; Zn < 5.5; Ni < 5.5; Ni < 5.5; Co < 5.5; Al < 4.5; Cu <4.5; Pb < 4.0; Fe^{3+} < 3.5.

Heavy metal content and pH values of soils

Although the heavy metal content of soils is partly a function of soil pH, the content of organic material and the permeability of the soil are also very important factors (*Kádár, 1991*). Our study investigates the heavy metal content and pH values of soils in two dolines in the Bükk and Aggtelek Mountains.

Table 1 Chemistry of soils in Aggtelek dolines (1998)

Sample	pH(H_2O)	PH(KCl)	pH(H_2O)-pH(KCl)
N (5-10)	6,10	5,24	0,86
N (10-20)	6,36	5,42	0,94
N (20-30)	6,58	5,81	0,77
N (30-40)	7,01	6,32	0,69
E (5-10)	**5,53**	4,52	1,01
E (10-20)	**5,64**	4,65	0,99
E (20-30)	6,17	5,16	1,01
E (30-40)	6,03	4,81	1,22
S (5-10)	7,05	6,53	0,52
S (10-20)	7,24	6,45	0,79
S (20-30)	7,20	6,03	1,17
S (30-40)	7,20	6,00	1,20
B (5-10)	**5,54**	4,70	0,84
B (10-20)	**5,68**	4,64	1,04
B /(20-30)	**5,86**	4,54	1,32
B (30-40)	**5,85**	4,70	1,15
B (40-50)	**5,70**	4,70	1,00
R (5-10)	**5,95**	5,14	0,81
R (0-20)	6,06	5,16	0,90
R /(20-30)	6,52	5,63	0,89
R (30-40)	6,29	5,09	1,20

Table 2.Chemistry of soils in Bükk dolines (1998):

Samples	$pH(H_2O)$	pH(KCl)	$pH(H_2O)$-pH(KCl)
N (5-10)	**5,90**	5,30	0,60
N (10-20)	**5,88**	5,26	0,62
N (20-30)	6,13	5,49	0,64
N (30-40)	6,12	5,24	0,88
E (5-10)	**5,87**	5,06	0,81
E (10-20)	**5,99**	5,23	0,76
E (20-30)	6,20	5,40	0,80
E (30-40)	6,20	5,09	1,11
S (5-10)	6,84	6,42	0,42
S (10-20)	7,37	6,88	0,49
W (5-10)	6,93	6,61	0,32
W (10-20)	7,20	6,85	0,35
B (5-10)	**5,03**	4,46	0,57
B (10-20)	**5,45**	4,77	0,68
B (20-30)	6,40	5,84	0,56
B (30-40)	6,51	5,84	0,67
B (40-50)	6,52	5,83	0,69

N = Northern slope; E = Eastern slope; S = Southern slope; W = Western slope.

Near the surface and on the bottom of dolines the soils are more acid than in the deeper soil horizons (*Table 1; Table 2*). The lower pH value supports the mobility of heavy metals.

According to our investigation the heavy metal content is higher in the karst soils than in the parent material (*Kevei-Bárány. - Hoyk. - Zseni, 1999*). The average heavy metal content of limestone according to Merian (1984) is the following (ppm): Mn 700; Fe 15.000; Co 2; Ni 15; Cu 4; Zn 23; Cd 0,165; Pb 5. Therefore, the heavy metal content of the studied soils originates from dry and wet depositions from the neighbouring industrial area (from the chemical factories of Sajó valley and industrial area of Slovakia).

Heavy metal content of plants

The uptake of heavy metals depends on the species of plant. Some authors have investigated the accumulator and excluder strategies of plants with respect to heavy metals (*Baker, 1981*). Metals can be concentrated in plants both in case of low and high background levels. *Peterson* (1971, 1975) listed twelve species with variation in plant/soil ratio for Zn, for Pb, for Cd and for Cu. There are three types of plant-soil relationship:

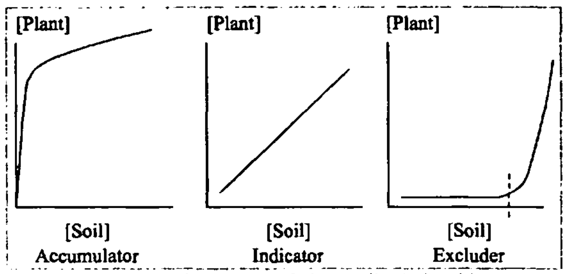

Fig. 1 The three types of plant-soil relationship

- Accumulators: the metals are concentrated in plant parts above ground both in case of low and high soil concentrations.
- Indicators: uptake and transport of metals to the shoot are regulated so that internal concentration reflects external level,
- Excluders: metal concentrations in shoot are maintained constant and low over a wide range of soil concentration, but above a critical soil value the mechanism breaks down and unrestricted transport will be the result (*Fig. 1*).

Accumulator and excluder plants are extreme types; indicators are intermediate types from the point of view of metal uptake.

As the origin of heavy metal contamination in karstwater is important, we need to know how much of the metal originates from the soil. Human activity has had a moderate impact on the investigated karst terrains. The depositions (wet and dry) have significant relation with the heavy metal content of karst soils.

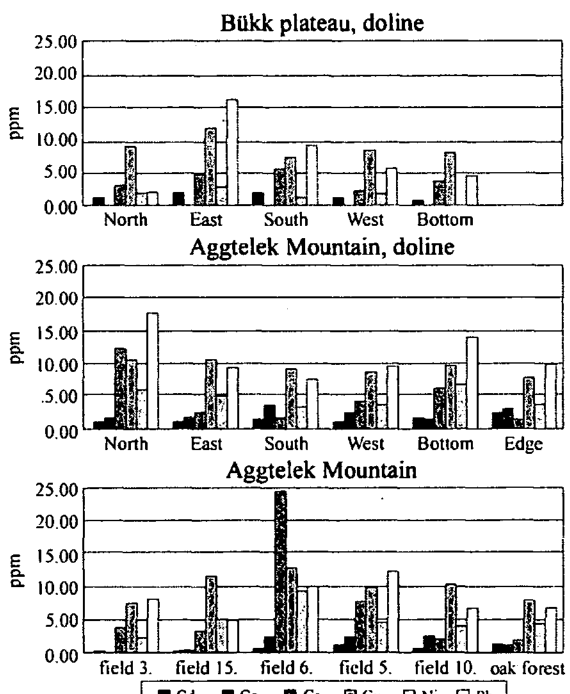

Fig. 2 The heavy metal content of the plants on different slope aspects

The following species occur in the grassy vegetation of the Aggtelek doline: *Dipsacus laciniatus, Cirsium arvense, C.vulgare, Eryngium campestre*; all are nitrophyllic grassy species indicating degradation. On the eastern slope *Sedum sexangulare, S. acre, Potentilla arenaria* are the dominant species. On the southern slope the dominant vegetation is composed of *Festuca, Agrostis and Arrhenaterum*. On the western slope *Agrostis, Festuca and Agrostis* species are characteristic in the grassy association, but *Juniper* can be found on the slopes as well. On the northern slope the vegetation is *Brachypodium pinnatum* with a forest steppe like environment.

The following species occur in the investigated doline in the Bükk: on the W, S and E slopes the dominant species are: *Potentilla*

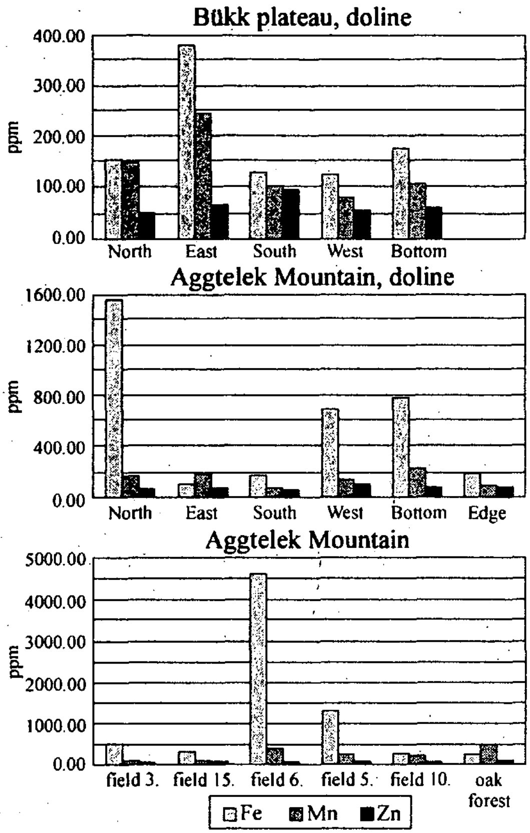

Fig. 3 The heavy metal content of the plants on different slope aspects

erecta, Succisa pratensis, Ranunculus auricomus, Rumex acetosa, Ribes alpinum.. On the S slope *Molinia coerulea, Astrantia major, Aegopodium podagraria, Lysimachia vulgaris, Anthriscus silvestris, Carduus nutans, Viola mirabilis* occur. On the N slope the dominant species are: *Salvia pratensis, Coronilla varia, Dianthus pontederae, Scabiosa ochroleuca, Polygala vulgaris, Digitalis ambiqua, Prunella grandifolia, Campanula persicifolia, Chalaminthа acinos.* The W, N and E slopes are covered by *Dactylis glomerata, Origanum vulgare, Geranium sanguineum, Teucrium chamaedrys, Galium verum, Trifolium alpestre, Poligonum convolvulus.*

In the doline mostly *indicator (Festuca, Campanula, Rumex,)* and *excluder (Viola, Lotus) species* occur. In the latter case the plants show limited metal accumulation.

Fig. 2 and *3* show the heavy metal content of plants in the investigated dolines in Bükk and Aggtelek and in some different ecological types of Aggtelek Mountains. Field 3 is bare tillage, where there was previously a vineyard and the soil was eroded. Field 5 is arable land, that drains to the Zomborlyuk swallet. The metals are derived from chemically polluted arable land. Field 6 is situated at the edge of a doline. Field 10 is on the karst cone of Közép Mountain. Field 15 is situated at the Red Lake. The red clay soil has lots of metals. We have collected soil samples from original oak forest, too.

At the bottom of dolines, where the pH vales are generally low, metal-ions can not accumulate, and it is possible that the plants took up the metals from seeping water. We have carried out a detailed investigation on the connection between soil pH and heavy metal content of plants. For the research Pb, Cd and Cr were chosen (*Fig. 4, 5, 6*).

The heavy metal content of the soil showed differences on the slopes located nearer or farther from the transportation routes. On the slopes of doline nearer to the routes and in the pinewoods on acid soils the heavy metal uptake of plants is more significant. For example, on the northern slope of the doline in Aggtelek, the road is on the edge of the doline. In its bottom high lead concentration was detected. In this case the pH value is low, therefore, the plants can take up more lead. The greatest lead value can find on the field near the Zombor-swallet. This swallet drains water from the agricultural area.

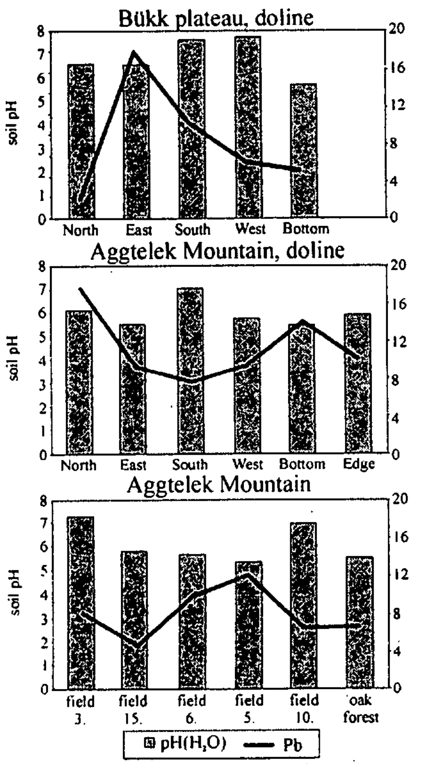

Fig. 4 The soil pH and Pb content of the plants on different slope aspects

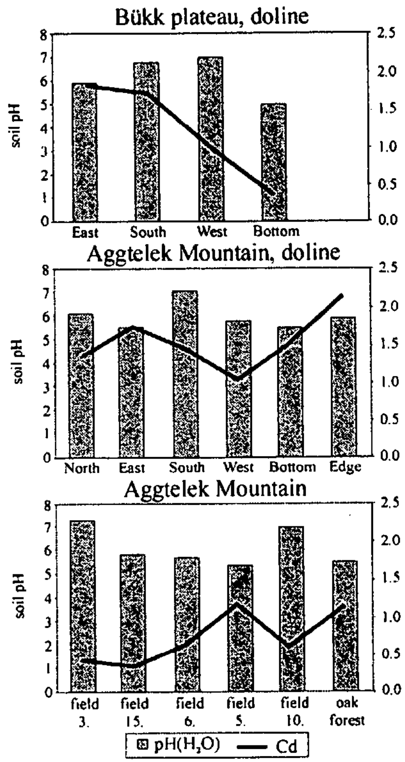

Fig. 5 The soil pH and Cd content of the plants on different slope aspects

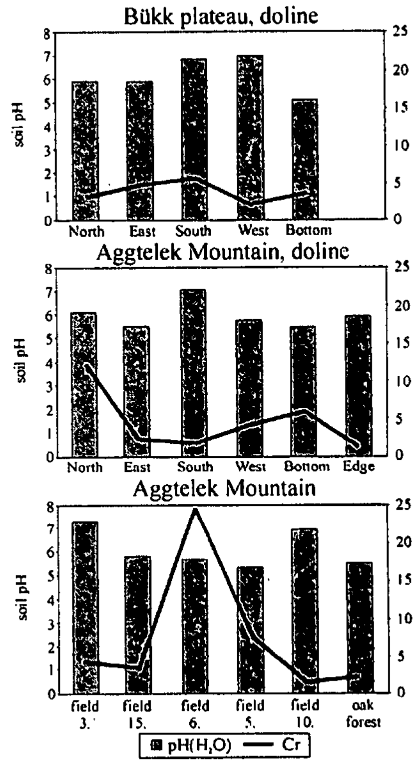

Fig. 6 The soil pH and Cr content of the plants on different slope aspects

Conclusions

Our investigation has demonstrated a relationship between soil pH and the heavy metal content of plants on karst territories:

1. The heavy metal content of vegetation is higher in the Aggtelek Karst than in the Bükk Mountains.
2. The heavy metal content changes with pH, if the soil pH is low, the heavy metal content of vegetation is higher than at higher pH values.
3. The content of heavy metal in plants is close to the maximum of heavy metal content of soils.
4. In Aggtelek, near the swallow-hole, the heavy metal values are high in close relationship with the land use.
5. In the doline of Aggtelek the highest metal values were measured on the northern slope, in the neighbourhood of the road.

In the future we would like to study the ratio of heavy metal content of soil and plants, because the higher ratios will show which are the accumulator plants in the investigated area.

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