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HEAVY METAL CONTENT OF SOME HUNGARIAN AND ENGLISH KARST SOILS

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Összefoglalás - A karsztokon kialakult talajok nehézfém-tartalmának vizsgálata nagy jelentőségű, mivel a Föld ivóvizeinek 25 %-át karsztvizek szolgáltatják. A szennyeződések (különösen a nehézfémek) igen veszélyesek a karsztos területeken. Amennyiben az oldatba kerülő nehézfémek a talajon keresztül szivárogva bekerülnek a karsztvízbe, az veszélyforrást jelent az ivóvizet használó lakosság számára. A nehézfémek többsége száraz és nedves ülepedésből származik, amelyek a talajok elszennyezése mellett azok elsavanyodásához is hozzájárulhat. A talajokban a nehézfémek a talajalkotó részecskékhez kötődnek. A nehézfémek talajoldatba kerülését a talajok megkötő képessége befolyásolja. Ez elsősorban a talajok kémhatásától, szerves-anyag- és agyagtartalmától, azaz a talajok puffer-kapacitásától függ. A nagy puffer-kapacitással rendelkező talajokban a veszélyes fémek a talajalkotókhoz kapcsolódva felhalmozódhatnak, így azok a talajoldatba kerülve nem érik el a karbonátos alapkőzetet. A nehézfémek mobilitása a talajok kémhatásának és szervesanyag-tartalmának csökkenésével párhuzamosan általában növekszik. A tanulmány néhány angol és hazai karsztos területen ismerteti a talajok nehézfém-tartalmát. A vizsgálatok a talajok kémhatása, szerves-anyag- és nehézfém-tartalma közötti kapcsolatot tárják fel. Az irodalomban kevés adatot találunk a karsztos területek talajainak nehézfém-tartalmáról, ezért a dolgozatban szereplő nehézfém szennyezettségi adatok jó alapot szolgáltatnak a további vizsgálatokhoz.

Summary - The heavy metal content of karst soils is a significant aspect of karst water because 25% of drinking water comes from the karstwater of the world. The pollution (especially the heavy metal pollution) of the soils is dangerous for karst areas. If the metals pass from the soil into the karst water it will be unhealthy for the population. Much heavy metal is inherited from dry and wet deposition. Acid dry and wet depositions bring pollution materials and give rise to acidification of soils. Soils which have appropriate characteristics can bind the heavy metals to the different soil particles. This power to prevent the heavy metals reaching soil solution mainly depends on the pH, the organic matter and clay content of the soils, namely on the buffering capacity of the soil. The soils with high buffering capacity can accumulate the dangerous metals in the soils and do not permit them to go to soil solution and thus to reach the limestone bedrock and finally the karst water. Generally, the mobility of heavy metals increases with decreasing pH and decreasing organic matter content of soils. Our paper presents the heavy metal content of karst soils in some English and Hungarian karst territories. The analysis of soils attempts to detect the connection between the organic matter content, pH and the heavy metal content of these soils. In the karst-literature we have as yet few data concerning heavy metal contamination of karst soils. Our data indicate the pollution level of karst soils. These data are a basic point for further investigations.

Key words: karst soil, heavy metal contamination, British Karsts, Aggtelek Karst, Mecsek Mountains

METHODS

We collected soil samples on Hungarian and English karst areas. The Hungarian samples came from the Aggtelek Karst and Mecsek Mountains; the English ones are from limestone areas of Northern England (*Figs. 1-5*). The studied area on Aggtelek Karst is in a National Park; the investigated western part of Mecsek Mountains (with the karstified Triassic limestone) is a projected protected area. There are differences in precipitation and height above sea level (Aggtelek area: 310-480 m, Western Mecsek: 300-450 m) in the two investigated Hungarian areas. The annual precipitation is 650-700 mm on Aggtelek Karst and 700 mm in Western Mecsek. The karst areas of Mecsek Mountains are situated in western direction from coal mining places (the main wind direction is north-west). Aggtelek Karst is situated south-east from Slovakian industrial areas and the next to this area the main Hungarian chemical industry was developed. Acid deposition is higher here than in the Mecsek Mountains.

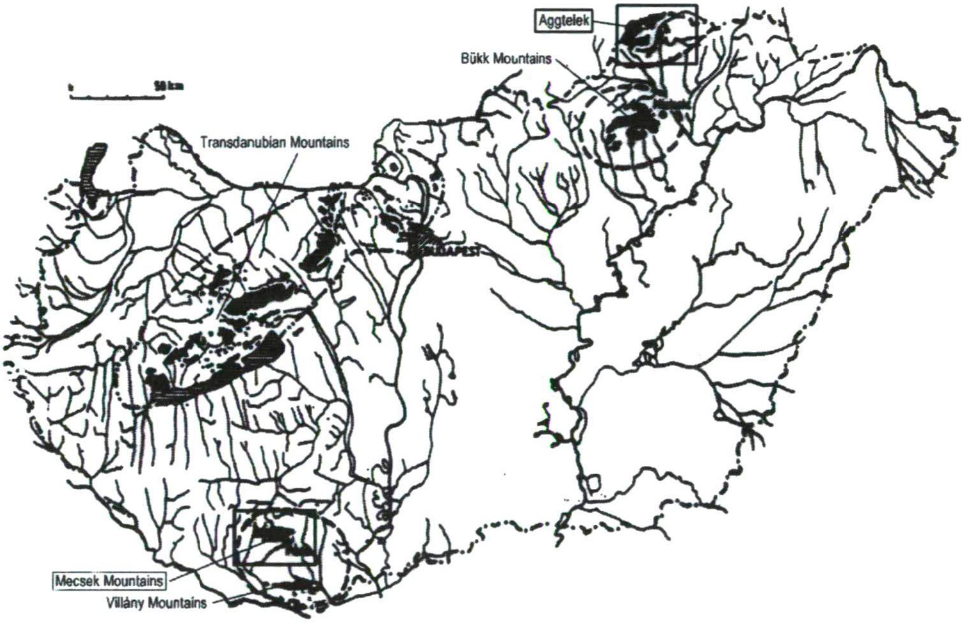

Fig. 1 Limestone regions in Hungary

Each collected soil occured on limestone bedrock. The soils are mainly rendzinas or rendzina like soils (unconsolidated) on Aggtelek Karst but we have some brown forest soil as well. The soils of Mecsek Mountains are mainly brown forest soils with clay illuviation (better consolidated), and there are some rendzinas. The Hungarian samples were collected in areas that represent different ecological conditions: different type of forests and fields. The English soils are thin soils covering limestone pavements (Carboniferous limestone). Some of them were collected on limestone pavements areas where there was mining activity (mainly lead) in the past. We have some English samples from dolinas as well. The thickness of the soils is mainly only 40 cm in the case of rendzinas, and they are mixed with limestone fragments (40-60%). The brown forest soils are deeper and usually there are no fragments in them. We chose the upper 10 cm soil layer to make comparison of pH, organic matter and heavy metal content of the soils in the different karst areas of Hungary and England. The organic matter accumulates near the surface and the heavy metals bind to humus colloids (We have data from deeper layers, too, but the main accumulation horizon is the uppermost level (A_0 level)).

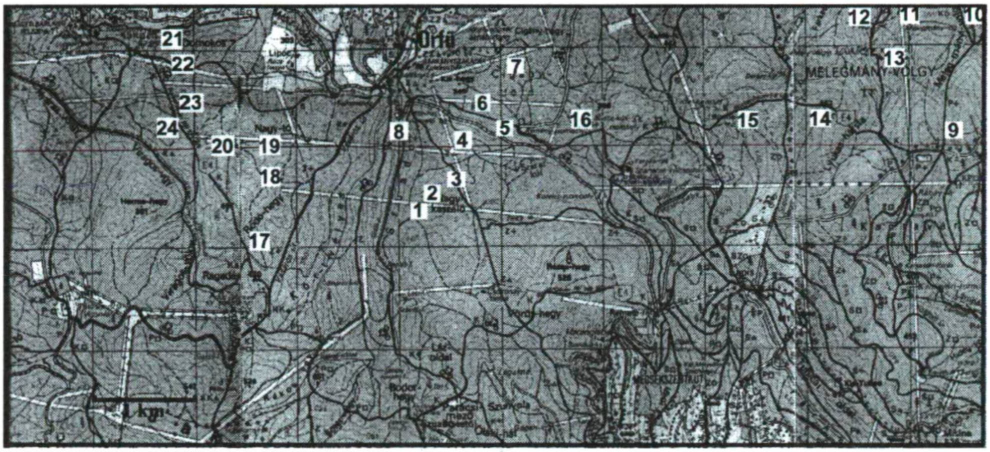

Fig. 2 Sample sites in Mecsek Mountains

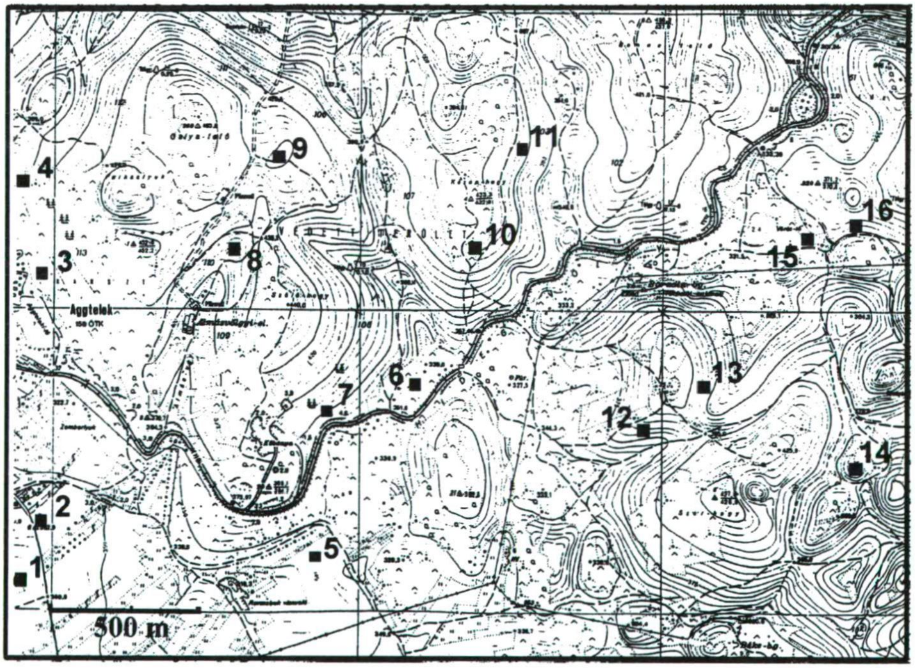

Fig. 3 Sample sites in Aggtelek Karst

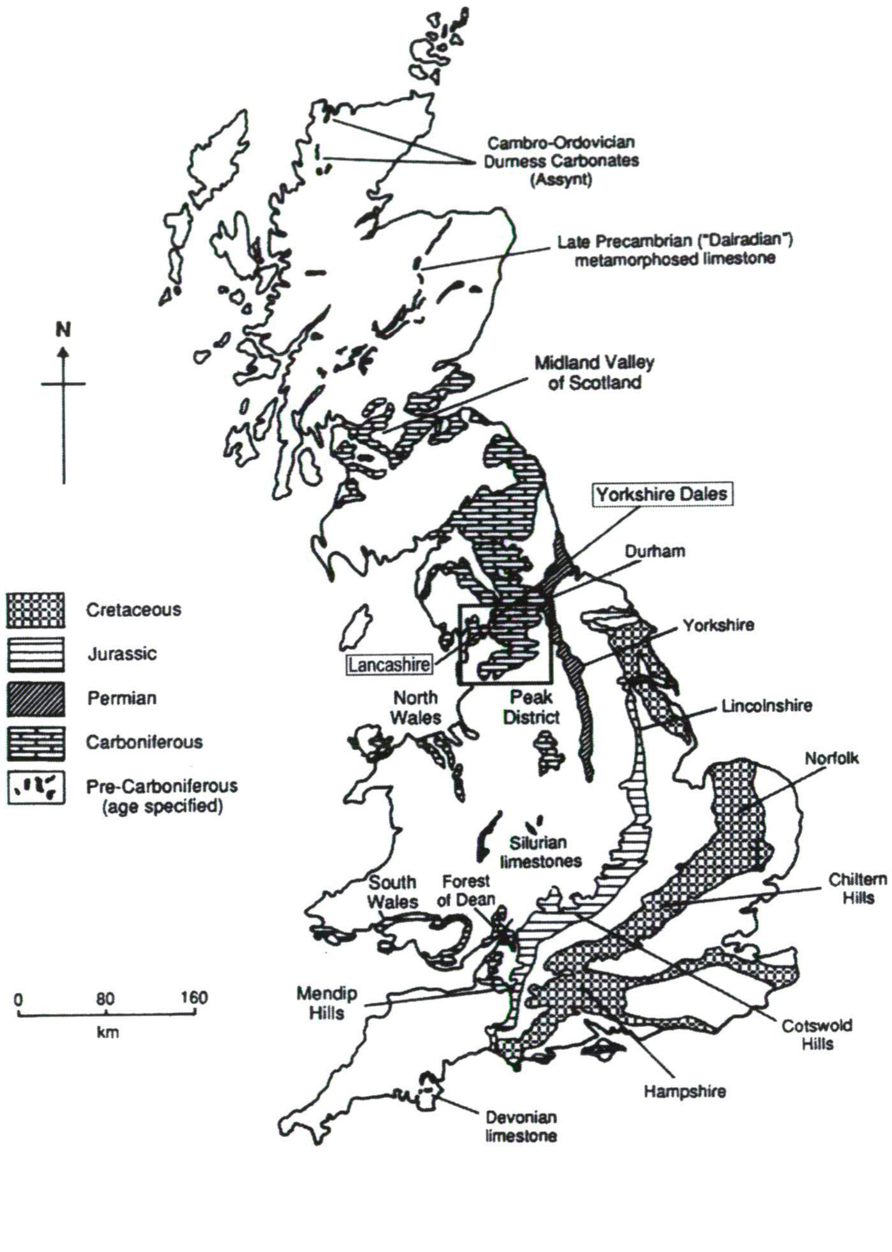

Fig. 4 Limestone regions in England

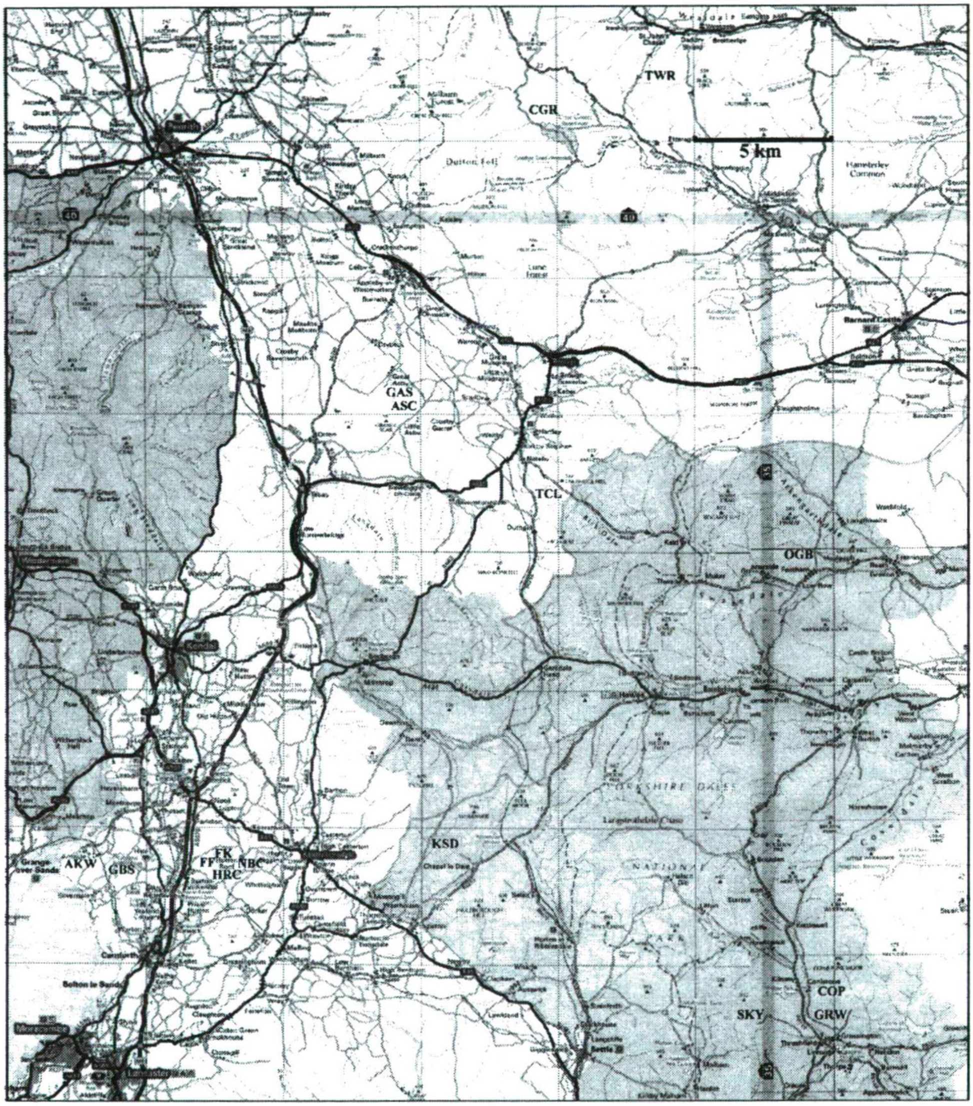

Fig. 5 Sample sites in England (Yorkshire Dales and Cumbria)

The pH was measured in distilled water with a digital pH-meter. The soil water ratio is 1 : 2.5 (6 g soil and 15 cm^3 water). The organic matter was oxidized in acid solution by $K_2Cr_2O_7$ and measured by spectrophotometer (Hungarian samples and the English samples: GAS 1, 5, TCL 5, 6, FF 7, NBC 2, COP 3, 4, HRC 9, 11, ASC 3.) The other English samples were measured by titration after $K_2Cr_2O_7$ oxidization. The heavy metals were extracted from all soils by aqua regia and measured by atomic adsorption spectrophotometer (Hungarian samples) and by ion-chromatography (English samples). This means that except for the heavy metals bound to the silicate mineral, all heavy metal content was measured. So we determined that part of the heavy metal content of soils which can be mobilized if the conditions of the environment change in some way.

DISCUSSION

Based on our earlier investigation the heavy metal content of karstic soils in Hungary is higher than it should be originating from the parent rock alone (*Keveiné Bárány et al.*, 1999). *Kádár* (1991) has already found that the near-natural environments in Hungary contain much more heavy metals than they would have if the heavy metals originated only from the parent material.

The heavy metal content of limestone is originally not too high. After *Kabata-Pendias and Pendias* (1984) the heavy metal contents of limestone and dolomite are: Cu: 2-10; Co: 0.1-30; Cd: 0.035; Ni: 7-20; Pb: 3-10 ppm. After *Merian*'s investigation (1984) the average concentration of heavy metals in limestone is the following: Cu: 4; Co: 2; Cd: 0.165; Ni: 15; Pb: 5; Zn: 23; Mn: 700 ppm.

After *Xiandong and Thorton* (1993) the multi-elements contamination of soils (for example of brown earth on the carboniferous limestone) is affected by underlying mineralised rock, by mining activities producing widespread contamination and by smelter pollution. The metal contamination of large areas of agricultural soils in England comes from mining, too (*Colbourn and Thorton*, 1978).

Brümmer et al. (1991) have established that increase of metal mobility is related to pH value: the different heavy metals go at different pH values to solution: Cd pH < 6.0-6.5; Mn pH < 5.5; Zn pH < 5.5; Ni pH < 5.5; Co pH < 5.5; Al pH < 4.5; Cu pH <4.5; Pb pH < 4.0; Fe^{3+} pH < 3.5 can be mobilized. From this it is clear that the lower pH values help the mobility of metals.

The classification of soil reaction in the different areas *(Table 1)* shows us that about half of the examined soils in Mecsek and Aggtelek Karst are acid and we can find strongly acid soils as well. The English samples are mainly weakly acid and acid.

The heavy metal contents, pH and organic matter content of the soils are in *Tables 2, 3, 4* as well as pollution limiting values.

Table 1 Classification of soil reaction

Chemical reaction after Stefanovits, (1992)	***Number of soil samples***		
$pH(H_2O)$	*Aggtelek*	*Mecsek*	*England*
strongly acid (pH below 4.5)	2	1	4
acid (pH 4.5-5.5)	**8**	**11**	**14**
weakly acid (pH 5.5-6.8)	3	8	**16**
neutral (pH 6.8-7.2)	1	2	3
weakly basic (pH 7.2-8.5)	2	1	4
Sum total	16	23	41

Table 2 Heavy metal content, pH and organic matter content of soil samples in Aggtelek Karst

Aggtelek	***Ecological***	***Heavy metals (ppm)***							***$pH(H_2O)$***	***Org. mat.%***
sample	***condition***	***Cd***	***Pb***	***Ni***	***Co***	***Cu***	***Cr***	***Mn***		
1	oak	**2.44**	96.0	**60.9**	22.7	**226.3**	54.0	678.8	5.49	15.1
2	stubble	0.48	29.9	23.9	14.5	**221.7**	40.6	636.0	7.66	16.3
3	field	**1.20**	43.9	**65.1**	17.6	**226.1**	72.2	636.7	7.31	12.6
4	oak	0.85	36.9	**56.0**	14.1	**204.3**	69.5	437.0	5.00	12.7
5	field	0.68	68.0	**48.1**	24.3	**222.8**	56.3	611.0	5.35	26.6

Table 2 (continued)

Aggtelek sample	*Ecological condition*	*Heavy metals (ppm)*							*pH(H_2O)*	*Org. mat.%*
		Cd	*Pb*	*Ni*	*Co*	*Cu*	*Cr*	*Mn*		
6	field	0.90	47.0	**46.4**	19.7	**222.2**	55.0	607.7	5.71	28.0
7	pine	0.90	42.4	**53.8**	14.3	**219.3**	67.9	502.2	5.21	15.8
8	oak	0.87	46.9	**43.9**	18.2	**232.9**	53.3	539.0	4.33	19.3
9	oak	**1.90**	75.4	**55.0**	15.7	**262.6**	62.0	649.8	5.00	72.6
10	field	1.60	56.3	**54.5**	14.9	**240.4**	62.5	597.2	7.03	77.8
11	oak	**2.00**	57.4	**57.7**	13.9	**271.0**	67.4	604.4	6.29	43.1
12	oak	0.74	58.3	**55.7**	13.9	**275.3**	65.0	558.9	4.85	29.7
13	oak	0.95	68.1	**78.6**	27.1	**270.2**	**87.9**	488.9	4.93	33.0
14	oak	**1.13**	56.5	**44.3**	20.8	**251.7**	52.3	584.3	4.86	18.0
15	field	0.98	56.9	**48.7**	18.1	**279.6**	53.6	561.4	5.77	32.3
16	oak	0.76	53.6	**45.6**	13.7	**277.2**	55.7	516.0	4.40	44.0
background concentration		0,5	25	25	15	30	30			
pol. lim. value in Hungary		1	100	40	30	75	75			
pol. lim. value in England		1	50	30		50	50			

Table 3 Heavy metal content, pH and organic matter content of soil samples in Mecsek Mountains

Mecsek sample	*Ecological condition*	*Heavy metals (ppm)*							*pH(H_2O)*	*Org.mat.%*
		Cd	*Pb*	*Ni*	*Co*	*Cu*	*Cr*	*Mn*		
1	oak	0.30	26.0	34.0	17.0	12.0	19.5	761.5	5.11	6.09
2	oak	0.30	25.0	35.0	16.0	13.0	21.0	778.5	5.98	16.65
3	oak	0.60	26.0	**44.5**	12.0	17.0	27.0	599.0	5.69	10.82
4	oak	0.55	22.5	33.0	14.0	10.5	18.0	572.5	4.74	9.63
5	oak	0.20	22.5	35.5	9.5	13.0	20.5	448.0	5.21	9.27
6	beech	0.50	24.5	**41.5**	13.0	13.5	20.5	1054.0	5.97	9.7
7	oak	0.35	22.5	**43.0**	11.5	17.0	23.5	1100.0	6.78	15.42
8	beech	**1.45**	42.0	**49.0**	16.5	21.0	25.5	1525.0	7.46	35.38
9	oak	0.20	30.5	36.5	14.0	17.5	22.0	1152.0	4.54	6.95
11	oak	0.30	16.5	29.0	9.0	12.0	18.5	323.5	4.66	11.32
12	oak	0.95	35.0	**52.5**	14.0	17.5	32.0	948.5	6.07	19.61
13	oak	0.35	23.0	36.0	12.0	14.0	23.0	704.0	6.8	17.53
14	beech	0.15	23.5	35.5	12.5	13.0	20.0	696.0	4.89	16.6
15	beech	0.55	26.5	38.5	12.0	12.0	20.0	1395.0	6.07	15.24
16	beech	0.10	17.5	29.0	10.0	10.0	17.5	579.0	4.15	7.08
17	oak	**1.05**	28.0	33.0	17.0	10.0	19.0	810.5	5.08	7.9
18	oak	**1.05**	32.0	**54.0**	17.0	20.0	29.0	1242.5	6.67	15.2
19	oak	0.70	23.0	**52.5**	15.0	19.5	26.0	713.5	6.53	8.71
20	beech	0.10	21.5	32.5	13.5	9.5	18.5	649.5	4.9	9.73
21	oak	0.30	23.0	38.0	11.0	16.0	24.0	1122.5	6.98	9.5
22	beech	0.35	25.5	38.5	19.0	13.5	20.0	704.5	4.54	12.94
23	beech	0.25	25.5	34.5	14.5	10.5	18.0	950.5	5.34	12.09
24	beech	0.15	22.5	34.0	11.5	9.5	19.0	474.0	4.75	3.81
background concentration		0.5	25	25	15	30	30			
pol. lim. value in Hungary		1	100	40	30	75	75			
pol. lim. value in England		1	50	30		50	50			

Table 4 Heavy metal content, pH and organic matter content of soil samples in England

England sample	***Ecological condition***	***Heavy metals (ppm)***						***pH(H₂O)***	***Org.mat.%***
		Cd	***Pb***	***Co***	***Cu***	***Cr***	***Mn***		
GBS 005	lim. pav	0.00	**6630.4**	**51.2**	0.0	61.4	2240.0	6.3	3.77
GBS 006	lim. pav.	0.00	**3560.5**	0.0	25.9	**85.8**	4923.6	6.2	3.6
GBS 007	lim. pav.	0.00	**14837.0**	0.0	0.0	56.4	5731.8	6.21	0.8
KSD 1	mining area	0.00	**8237.3**	0.0	0.0	26.5	253.3	4.95	4.5
FK 1/A	doline	0.00	**9198.5**	0.0	0.0	34.9	1013.2	3.69	9.1
FK 1/B	doline	0.00	**4467.1**	0.0	0.0	64.2	2744.1	4.53	2.4
FK 2/A	doline	**387.60**	**7258.4**	0.0	0.0	26.6	0.0	3.93	6.7
FK 2/B	dolne	**752.20**	**8725.4**	0.0	0.0	27.8	961.1	4.69	1.7
FK 2/C	dolne	0.00	**16148.9**	0.0	**194.2**	**75.6**	1618.1	4.9	1.07
FK 3/A	doline	0.00	**8000.0**	0.0	0.0	19.0	0.0	4.26	5.08
FK 3/B	doline	**1965.40**	**22012.6**	0.0	0.0	73.5	3223.3	4.54	2
AKW 1	woodland	0.00	**7171.7**	**692.6**	64.9	55.9	938.0	5.56	5.5
AKW 2	woodland	0.00	**7146.3**	0.0	0.0	57.3	726.7	5.03	3.7
TCL 001	lim. pav.	**413.70**	**7068.5**	**142.7**	0.0	**93.0**	8915.8	5.62	4.7
TCL 003	lim. pav.	0.00	**13015.2**	0.0	**169.7**	**118.6**	13078.8	7.18	13.5
TCL 004	lim. pav.	0.00	**7720.5**	**47.3**	**279.5**	**97.0**	1048.0	6.84	6.6
TCL 007	lim. pav.	0.00	**2852.1**	**65.4**	**120.7**	73.5	2163.0	6.17	10.9
CGR 002	mining area	0.00	**8046.3**	0.0	12.2	28.2	0.0	4.48	14.7
CGR 003	mining area	**116.60**	**2718.6**	**51.3**	0.0	29.1	4010.3	7.83	2.8
CGR 005	mining area	0.00	**4994.4**	**36.0**	**121.5**	29.3	5624.3	5.05	4.3
CGR 006	mining area	0.00	**31491.1**	**401.5**	67.7	33.0	7985.6	6.54	5
SKY 001	lim. pav.	**349.00**	**3901.5**	**62.2**	0.0	61.3	3920.6	5.89	8
SKY 002	lim. pav.	0.00	**3084.2**	0.0	0.0	70.4	2514.0	5.44	8.2
SKY 003	lim. pav.	0.00	**13970.8**	0.0	**103.5**	**123.6**	426.3	5.92	5.9
SKY 004	lim. pav.	0.00	**3137.0**	0.0	**188.9**	**93.5**	3877.7	5.93	5.4
GRW 002	woodland	**6.50**	84.3	0.0	0.0	**83.3**	2851.6	7.55	7.9
GRW 003	woodland	0.00	**12810.3**	**34.8**	**94.3**	**79.3**	2532.3	5.35	4.3
OGB 001	mining area	0.00	**2797.4**	**38.0**	0.0	6.1	971.9	5.85	8.7
OGB 002	mining area	0.00	**4126.4**	0.0	**4814.9**	20.2	1428.9	7.31	4.1
TWR 002	mining area	0.00	**2284.0**	0.0	0.0	2.9	568.0	5.22	5.6
GAS 1	lim. pav.	0.00	**11208.1**	0.0	0.0	40.4	516.1	5.2	28.18
GAS 5	lim. pav.	0.00	**350.0**	0.0	0.0	45.1	762.8	4.56	23.42
TCL 5	lim. pav.	0.00	**358.0**	4.6	**78.0**	**186.0**	6975.7	6.89	32.25
TCL 6	lim. pav.	0.00	**13001.8**	**55.2**	**214.9**	97.2	1411.9	4.93	18.15
FF 7	lim. pav.	0.00	**4095.1**	0.0	**95.1**	**97.6**	618.3	5.95	13.67
NBC 2	lim. pav.	0.00	**768.0**	0.0	0.0	**83.4**	52.2	5.69	25.98
COP 3	lim. pav.	0.00	0.0	0.0	0.0	0.0	0.2	6.05	19.39
COP 4	lim. pav.	0.00	**3285.2**	0.0	47.2	**86.9**	6979.8	6.23	19.31
HRC 9	lim. pav.	0.00	0.1	0.0	0.0	0.0	0.3	5.74	32.04
HRC 11	lim. pav.	0.00	**666.7**	0.0	63.5	11.7	498.9	4.61	32.21
ASC 3	lim. pav.	0.00	**5561.2**	0.0	**183.1**	**115.3**	2780.6	7.26	37.15
background concentration		0,5	25	15	30	30			
pol. lim. value in Hungary		1	100	30	75	75			
pol. lim. value in England		1	50		50	50			

The organic matter content of the soils on Aggtelek Karst is higher than in Mecsek. This is because of the different soil type: the rendzinas have usually much more higher organic matter content than the brown forest soils have. The English samples can be divided into two parts according to the different methods. The samples which organic matter content were determined by titration have lower contents than the soils of spectrophotometer's method.

CONTENT OF HEAVY METALS IN THE DIFFERENT SAMPLES

Cadmium: There are only 3 samples in Mecsek and 5 samples on Aggtelek Karst where the Cd content is much higher than the permitted value. There is no Cd in most cases of the English soil samples but there are 7 samples where the Cd content is much higher than the pollution limiting value. Only one of these extremely high Cd polluted samples are on mining areas, 3 of them are in dolinas.

Lead: The Pb content of soils is lower in every sample in Hungary than the pollution limiting value. The data are a bit lower in Mecsek than on the Aggtelek Karst. According to the limiting value of England, most samples of Aggtelek Karst must be qualifed as polluted. There are only 3 of the 41 English samples where the soils have not higher Pb content than the permitted value. The Pb contents are very high, not only on mining areas but in other areas as well. The data are 20-200 times higher than the permitted value.

Nickel: Almost all of the samples on Aggtelek Karst have higher Ni content than the pollution limiting value (average 50-70 ppm). The situation is better in Mecsek, where only 7 of the 23 samples have higher Ni content than 40 ppm. If we investigate the limiting value of England (30 ppm) then the Mecsek samples must be considered as polluted. The Ni content of the soil samples of England was not measured.

Cobalt: In respect of Co the condition of soils is good in the investigated Hungarian areas. There is no soil with Co content higher than the permitted level. 12 of the English samples are polluted and some of these samples have very high Co content. In the other English samples the method which was used was not able to show any Co.

Copper: Every soil sample in the Aggtelek Karst has a high Cu content, above 200 ppm. The values are about 3 times higher than the pollution limiting value of Cu. A smaller part of the English soils have higher Cu contents than the permitted level and the data are about as high as on the Aggtelek Karst. There is one very polluted sample in an English mining area. The situation is the best in Mecsek, where we did not find any samples with Cu content higher than the limit.

Chromium: Just as in the case of the other heavy metals, the condition of soils is the best in Mecsek Mountains as regards Cr. All samples on Aggtelek Karst have a higher Cr content than the pollution limiting value of England. But if we investigate the problem in respect of the Hungarian limit then only 1 sample exceeds the limit. The English samples have the highest Cr contents, a lot of them are above the limiting value.

Manganese: The soils on Aggtelek Karst have the lowest Mn content of the 3 areas. The samples of Mecsek have slightly higher values but we found the highest Mn content in the English samples. The Hungarian soils reflect the average Mn content of limestone (700 ppm).

TENDENCIES OF HEAVY METAL CONTAMINATION

The soil samples in Mecsek Mountains are in the best condition in view of heavy metals. There are problems only in the case of Ni (almost in all soil samples if we consider the English pollution limiting value), and the Cd content of some soils is a little higher than permitted.

On the other Hungarian area the condition of the soils is worse. In respect of Pb and Co we did not find problems. But the Ni and Cu contents are higher than the Hungarian pollution limiting values. If we consider the limiting values of England than the Cr and Pb contents of soils are higher than the permitted values. In 5 samples the Cd content causes problems as well.

Cu becomes more mobile when pH < 4.5 so at the present time this heavy metal is not so mobile in the soils of Aggtelek Karst because the pH of soils > 4.5 in most cases. The Ni - which tends to go to solution pH under 5.5 - can cause greater problems than Cu while there are a lot of acid soils (pH < 5.5) both in Mecsek and on Aggtelek Karst. In these soils the mobility of Ni increases. The mobility of Cd increases when pH < 6.0-6.5 so we have to pay attention to the polluted soils especially on Aggtelek Karst. The mobility of Pb is not so great when pH > 4.0 so at this moment the condition of soils is good to retain the lead.

The English soil samples have higher heavy metal contents. There are many soils in which the Cd, Co and Cu contents are not traceable but in the other samples these heavy metals present in a very high quantity. In the case of Pb and Cd the overstep of pollution limiting values are extraordinarily high. This can cause very serious problems while the low organic matter content and acid reaction of soils cannot retain such quantities of heavy metals even if the mobility of metals is not so great in normal cases in such soil reactions. The higher heavy metal contents in England are partly caused by the more intensive anthropogenic effects: the mining of lead and other, usually non-ferrous metals have polluted the soils with heavy metals. On the other hand this pollution probably comes from areas of volcanic rocks in North-West England. These metals were transported within glacial debris on to the limestone areas. There was no mining activity in the investigated Hungarian areas. Here the soils are polluted mainly by deposition.

Table 5 Correlation coefficients in the different study areas

	Correlation coefficient						
	Cd	***Pb***	***Co***	***Cu***	***Cr***	***Mn***	***Ni***
Mecsek pH	0.5593	0.4739	0.1080	**0.6976**	**0.6652**	**0.6388**	**0.6919**
Mecsek org. mat.	**0.6062**	**0.6689**	0.2373	0.5338	0.4517	0.5500	0.4768
Aggtelek pH	0.1159	-0.2980	-0.1915	-0.2680	-0.1414	0.5131	-0.1756
Aggtelek org. mat.	0.3753	0.2999	-0.2237	0.4843	0.1066	0.1819	0.1228
England pH	-0.2423	-0.1322	0.0932	0.2886	0.3792	0.4500	
England org. mat.	-0.2299	-0.3681	-0.1685	-0.1000	0.1558	-0.0989	

For the investigation of the connection between pH and heavy metal content and the connection between organic matter content and heavy metal content we determined the correlation coefficients of these data (*Table 5*). In the soils of Aggtelek Karst and England we cannot find any connection, the coefficient values are low. But generally we can confirm in the case of soils in Mecsek that the higher the organic matter content the higher the heavy metal content. This is true for the pH as well: the lower the pH the lower the heavy metal content. For Cu, Cr, Mn and Ni the connection is closer to pH than organic matter content (*Fig. 6*). For Cd and Pb the organic matter content has stronger effect (*Fig. 7*).

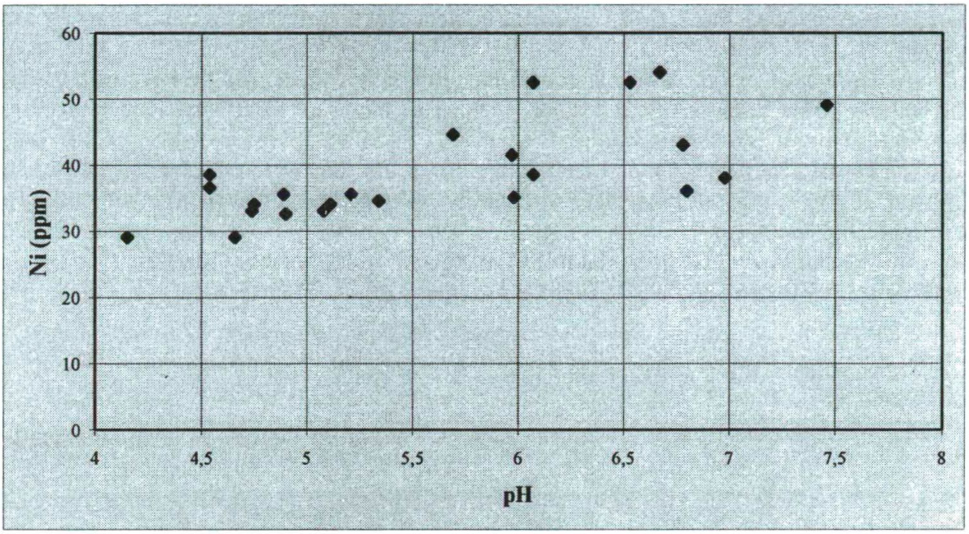

Fig. 6 Connection between Ni content and pH, Mecsek

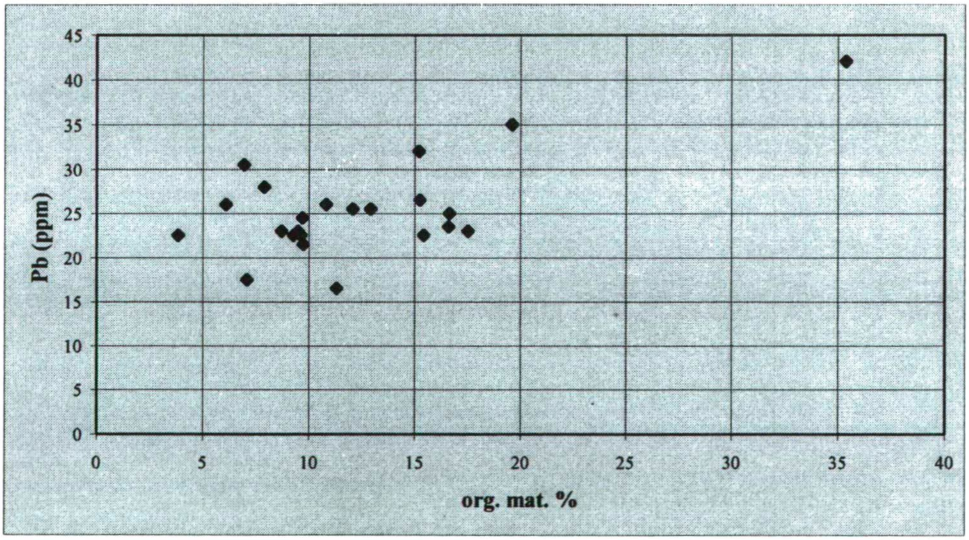

Fig. 7 Connection between Pb and organic matter content, Mecsek

CONCLUSION

At lower pH heavy metals leach from the upper soil layer into the deeper soil layers so the quantity of them is lower in the upper soil layer. The soils with higher organic matter content and higher pH can bind and hold back more+ heavy metals. The greatest problems are in the soils where the high heavy metal content meets low organic matter content and low pH.

The heavy metal contamination in Hungary is not too high. We have to conserve this soil condition because of the further leaching of metal ions will cause problems with the water quality in the karst system.

We detected higher metal contamination on the limestone pavements in Northern England. It means that in these areas the quality of karstwater must be affected and need protection.

Our data were the first data from the Hungarian territories. These data furnish the basis for further investigation of heavy metal contamination of karstic areas.

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