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Method OF INAA for Critical Evaluation Pollution of Ecosystem

Blanka Maňkovská and Július Oszlányi
Institute of Landscape Ecology, Slovak Academy of Sciences, Bratislava Slovakia

1. Introduction

The heavy metals in mosses biomonitoring network was originally established as a Swedish initiative (Rűhling, Tyler, 1968, 1971). It is assumed that in Slovakia (SK) a large gradient of atmospheric deposition load of elements exists, because part of the SK territory belongs to one of the most polluted areas in central Europe known as the 'Black Triangle II'. In order to recognise the distribution of element deposition in SK, the moss monitoring technique, also known as bryomonitoring, was applied to the whole territory in 1990, 1995, 1996, 1997, 2000 and 2005 (Maňkovská, Oszlányi, 2008). Bryomonitoring is a suitable technique using moss analysis to determine the levels of atmospheric deposition of the elements. The technique has been highly standardised and international bryomonitoring programs coordinated by Nordic countries have a pan-European character (Harmens et al.2008; Maňkovská, 1997; Maňkovská et al. 2003; 2008a b; Schröder et al.2008; Suchara et al. 2007; Zechmeister et al. 2003). These are characterized by a high concentration of toxic elements such as As, Cd, Cr, Cu, Hg, Fe, Mn, Ni, Pb, V and Zn. The aim of this paper is to present actual data of the first survey of 9 elements in mosses (*P. schreberi, H. splendens* and *Dicranum* sp.) in five Slovak sites: National parks (Vysoké Tatry, Nízke Tatry, Západné Tatry, Slovenský raj) and Landscape protection area (Veľká Fatra) and Báb Research Sites. An additional aim of this report is to summarize changes in heavy metal concentrations in mosses in Slovakia between 1990 and 2005 and to summarize concentration of Ag, Al, As, Au, Ba, Br, Ca, Ce, Cl, Co, Cr, Cs, Fe, Hf, I, In, K, La, Mg, Mn, Mo, Na, Ni, Rb, Sb, Sc, Se, Sm, Sr, Ta, Tb, Th, Ti, U, V, W, Yb, Zn, Zr in mosses in Slovakia for 2000.

2. Material and methods

The mosses *P. schreberi, H. splendens* and *Dicranum* sp. have been taken in compliance with the international methods (ICP, 1994) in permanent areas situated at the intersection of a 16 x 16 km pan-European network. Moss samples were collected according to the procedures used in deposition surveys in the Scandinavian countries. The collection of samples was performed during the first half of August 1990, 1995, 1996, 1997, 2000 and 2005. The samples consisted of the last three years' annual segments. Separately, the Vysoké Tatry, Nízke Tatry, Západné Tatry–Jelenec and Slovenský raj National parks, Veľká Fatra in Landscape protection area and the Báb Research Sites were evaluated.

Neutron activation analysis (NAA) was performed in 2000 in the Frank Laboratory of Neutron Physics, Dubna, Russia for 39 elements (Ag, Al, As, Au, Ba, Br, Ca, Ce, Cl, Co, Cr, Cs, Fe, Hf, I, In, K, La, Mg, Mn, Mo, Na, Ni, Rb, Sb, Sc, Se, Sm, Sr, Ta, Tb, Th, Ti, U, V, W, Yb, Zn, Zr). In the laboratory, the samples were carefully cleaned from needles, leaves, soil particles and only the green and green-brown shoots representing the last three years growth were analyzed, after being air-dried to constant weight at 30–40 °C for 48 hours. The samples were neither washed nor homogenised. For short-term irradiation samples of about 300 mg were pelletized in simple press forms and heat-sealed in polyethylene foil. For epithermal neutron activation analysis samples prepared in the same manner were packed in aluminium cups for long-term irradiation. The samples were irradiated in the IBR-2 fast-pulsed reactor, in channels equipped with a pneumatic system. The neutron flux characteristics are shown in table 1. Two kinds of analysis were performed: to determine short-lived radionuclides the samples were irradiated for 3 minutes in the second channel (Ch2), and to determine elements associated with long-lived radionuclides samples were irradiated for 100 hours in the cadmium screened Ch1. After irradiation gamma-ray spectra were recorded twice for each irradiation using a high-purity Ge detector: the first one after decay periods of 2–3 minutes for 5 minutes, and the second one for 20 minutes, 9–10 minutes after the short irradiation. For long irradiation, samples were repacked into clean containers and measured after 4–5 days for 45 minutes, and after 20–23 days for 3 hours (Frontasyeva, Pavlov, 2000).

Irradiation position	Neutron flux density, $[n\times cm^{-2}\times s^{-1}]\times1012$		
	thermal (E = 0÷0.55 eV)	resonance (E = 0.55÷105 eV)	fast (E = 105÷25.106 eV)
Ch1 (Cd-screened)	0.023	3.3	4.2
Ch2	1.23	2.9	4.1

Table 1. Flux parameters of irradiation positions

The atomic absorption spectrometer Varian Techtron was used to determine concentrations of Cd, Cr, Cu, Hg, Ni, Pb and Zn. The elemental analyser LECO SC 132 was applied to determine the concentration of sulphur, and the elemental analyser LECO SP 228 was used to determine the total concentration of nitrogen.

The valid equation [concentration in moss] $mg.kg^{-1}$ = [4x atmospheric deposition] $mg.m^{-2}.year^{-1}$was used (Steinnes et al. 2001). The analysis results were interpreted in the form of contamination factors K_F as the rates median value of element in Slovak mosses C_{iSl} vs. Norway mosses C_{iN} ($K_F = C_{iSl}/ C_{iN}$). Median Norway value C_{iN} were taken from Steinnes et al. (2001).

The accuracy of data was verified by analysis of standard plant samples and by comparison with the results obtained in 109 laboratories within the IUFRO working group for quality assurance (Hunter, 1994). The QC of NAA results were ensured by analysis of reference materials: trace and minor elements in lichen IAEA-336 (International Atomic Energy Agency), IAEA-SL-1 (Trace elements in lake sediment) and SRM-1633b (Constituent elements in coal fly ash, US NIST-National Institute of Standards and Technology), SRM-

2709 (Trace elements in soil). For an assessment of vegetation we used current statistical methods, factor and correlation analysis.

3. Results and discussion

The results of analysing the concentration of 45 elements in the mosses (*P. schreberi, H. splendens, Dicranum* sp.) are given in Table 2. We present separate loading for Báb Research Sites, National Parks (NP) - Vysoké Tatry; Nízke Tatry; Západné Tatry - Jelenec valley; Slovenský raj, the Landscape protection area (LPA) of Veľká Fatra and for Slovakia. For comparison with a pristine territory the corresponding data for northern Norway (Steinnes et al., 2001) is shown in the left-hand column. Comparison with the limit values from Norway (Table 2) shows strong pollution of the examined areas of Slovakia with most of the elements. However, for Au, N, S and Zr data from Norway was not available.

Excesses of concentrations of elements in mosses in comparison with Norway were expressed by the coefficient of loading by air pollutants K_F and classified it into 5 classes; class 1 – elements are in normal standard concentrations and the coefficient does not exceed the value 1; class 2 – light loading (coefficient of loading ranges from 1 to 10); class 3 – moderate loading (coefficient ranges from 10 to 50); class 4 – heavy loading (coefficient ranges from 50 to 100) and class 5 – toxic (coefficient is higher than 100). As shown in Table 3, the coefficient of loading by air pollutants K_F for almost all elements is higher than one, excerpt for Au, Br, In, Mg, N, S, Se (Báb); Au, Br, Ca, I, Se (Vysoké Tatry); Au, Br, I, Mg, S, Se, Sm, Ti (Nízke Tatry); Au, Br, Ca, Hg, I, In, Mg, S, Se, Sm (Západné Tatry-Jelenec); Au, Br, In Sm, Se (Slovenský raj) and Au, Br,In Sm (Veľká Fatra).

Spatial trends of element concentrations in mosses were metal-specific. However in general the lowest concentrations were observed in the Nízke Tatry National park, and 10 times higher concentrations occurred in the Vysoké Tatry (Al, Cr, Hf, Sb, Ta, Yb, Zr); Západné Tatry (Cr, Hf, Sb, Yb, Ta, Zr); Slovenský raj (Ag, Hg, Hf, Mo, Pb, Ta, Tb, Yb, Zr); Veľká Fatra (Cr, Hf, Sb, Ta, Tb, Th, Yb, Zr), Báb (Al, Cd, Ce, La, Hf, Mo, Pb, Sb, Sc, Ta, Tb, Th, Yb, Zr) in comparison to the Norway values. The coefficient of loading by air pollutants K_F ranged from 4.2 in the Nízke Tatry to 11.8 in Slovenský raj. Since 1990, the metal concentration in mosses has declined for Cd, Cr, Cu, Fe, Hg, Ni, Pb, Zn (Fig. 1, 2, 3).

Element	**Báb** (n=40)		**Vysoké Tatry** (n=3)		**Nízke Tatry** (n=4)		**Západné Tatry** (n=14)		**Slovenský Raj** (n=5)		**Veľká Fatra** (n=6)		**Slovakia** (n=86)		**Norway**	
	Aver.	Exc.	Aver.	Exc.	Aver.	Exc.	Aver.	Exc.	Aver.	Exc.	Aver.	Exc.	Aver.	Exc.	Aver.	Exc.
Ag	0.021	4.2	0.031	6.2	0.027	5.4	0.033	6.6	0.072	14.4	0.032	6.4	0.038	7.6	0.005	1
Al	968	11.0	888	10.1	345	3.9	735	8.4	708	8.0	769	8.7	966	11.0	88	1
As	0.21	6.8	0.2	6.7	0.15	5.0	0.18	6.0	0.28	9.3	0.19	6.3	0.2	6.7	0.03	1
Au**	0.001	0.2	0.001	0.5	0.001	0.5	0.001	0.5	0.001	0.5	0.001	0.5	0.001	0.5	0.002	-
Ba	11.3	2.4	8.8	1.8	8.8	1.8	12.5	2.6	21.5	4.5	11	2.3	15.4	3.2	4.8	1
Br	1.16	0.9	1.03	0.8	0.78	0.6	0.85	0.7	0.81	0.6	0.95	0.8	0.91	0.7	1.25	1
Ca	1998	2.6	722	0.9	1006	1.3	113	0.1	1036	1.3	1485	1.9	1322	1.7	780	1
Cd	0.20	10.1	0.1	5.0	0.12	6.0	0.15	7.5	0.14	7.0	0.16	8.0	0.16	8.0	0.02	1
Ce	1.04	12.1	0.45	5.2	0.463	5.4	0.61	7.1	0.68	7.9	0.77	8.9	0.98	11.4	0.086	1
Cl	53	1.1	68	1.4	99	2.0	80	1.6	74	1.5	52	1.0	70	1.4	50	1

Co	0.28	6.5	0.28	6.6	0.13	3.1	0.34	8.0	0.41	9.4	0.32	7.3	0.38	8.8	0.043	1
Cr	1.64	9.7	1.83	10.8	0.8	4.7	1.8	10.6	1.41	8.3	2.33	13.7	2.18	12.8	0.17	1
Cs	0.10	3.3	0.13	4.3	0.2	6.7	0.12	4.0	0.11	3.7	0.11	3.7	0.13	4.3	0.03	1
Cu	2.29	2.1	2.1	1.9	1.6	1.5	5.5	5.0	4.1	3.7	2.1	1.9	2.5	2.3	1.1	1
Fe	437	4.8	425	4.7	186	2.0	377	4.1	455	5.0	497	5.5	555	6.1	91	1
Hf	0.163	81.5	0.128	64.0	0.055	27.5	0.131	65.5	0.125	62.5	0.125	62.5	0.168	84.0	0.002	1
Hg	0.047	3.6	0.034	2.6	0.032	2.5	0.01	0.8	0.147	11.3	0.039	3.0	0.102	7.8	0.013	1
I	0.7	1.5	0.3	0.6	0.4	0.8	0.4	0.8	0.7	1.4	0.5	1.0	0.5	1.0	0.50	1
In	0.02	0.4	0.05	1.0	0.12	2.4	0.04	0.8	0.04	0.8	0.02	0.4	0.04	0.8	0.05	1
K	1908	2.5	2362	3.1	2269	3.0	1936	2.6	1753	2.3	1674	2.2	1770	2.4	750	1
La	0.77	11.0	0.23	3.3	0.32	4.6	0.35	5.0	0.51	7.3	0.58	8.3	0.62	8.9	0.07	1
Mg	374	1.0	373	1.0	262	0.7	354	0.9	393	1.0	387	1.0	436	1.1	386	1
Mn	96	1.2	114	1.4	89	1.1	135	1.6	141	1.7	92	1.1	110	1.3	83	1
Mo	0.31	10.2	0.17	5.7	0.24	8.0	0.28	9.3	0.3	10.0	0.26	8.7	0.27	9.0	0.03	1
N*	5500	1.0	6642	1.2	5494	1.0	6268	1.1	5520	1.0	5407	1.0	5927	1.1	5638	-
Na	120	2.4	81	1.6	107	2.1	82	1.6	109	2.2	90	1.8	129	2.6	50	1
Ni	0.88	3.1	0.78	2.8	0.38	1.4	0.84	3.0	0.53	1.9	0.98	3.5	0.99	3.5	0.28	1
Pb	8.6	12.3	5.1	7.3	4	5.7	5.3	7.6	12.9	18.4	6.3	9.0	8.3	11.9	0.7	1
Rb	2.85	1.2	7.5	3.0	9	3.6	5.1	2.1	3.15	1.3	4.13	1.7	4.26	1.7	2.48	1
S*	464	0.9	492	1.0	404	0.8	473	0.9	596	1.2	511	1.0	502	1.0	508	-
Sb	0.19	19.3	0.17	17.0	0.13	13.0	0.2	20.0	2.06	206.0	0.24	24.0	0.38	38.0	0.01	1
Sc	0.165	11.0	0.118	7.9	0.048	3.2	0.105	7.0	0.11	7.3	0.143	9.5	0.153	10.2	0.015	1
Se	0.087	0.9	0.08	0.9	0.055	0.6	0.08	0.9	0.07	0.8	0.098	1.1	0.095	1.0	0.093	1
Sm	0.115	1.3	0.038	0.4	0.053	0.6	0.051	0.6	0.058	0.7	0.07	0.8	0.088	1.0	0.086	1
Sr	22.5	7.8	13.5	4.7	7	2.4	15.8	5.4	14	4.8	14.5	5.0	21.6	7.4	2.9	1
Ta	0.024	24.0	0.017	17.0	0.008	8.0	0.017	17.0	0.016	16.0	0.02	20.0	0.023	23.0	0.001	1
Tb	0.030	30.0	0.007	7.0	0.005	5.0	0.01	10.0	0.013	13.0	0.017	17.0	0.02	20.0	0.001	1
Th	0.133	13.3	0.05	5.0	0.05	5.0	0.08	8.0	0.09	9.0	0.11	11.0	0.13	13.0	0.010	1
Ti	9.5	1.6	16	2.7	3.8	0.6	11.6	2.0	9.3	1.6	10.3	1.7	14.3	2.4	5.875	1
U	0.028	7.0	0.018	4.5	0.033	8.3	0.025	6.3	0.025	6.3	0.028	7.0	0.035	8.8	0.004	1
V	1.575	4.6	1.13	3.3	0.71	2.1	1.48	4.4	1.24	3.6	1.88	5.5	1.85	5.4	0.34	1
W	0.078	2.6	0.05	1.7	0.08	2.7	0.07	2.3	0.08	2.7	0.08	2.7	0.07	2.3	0.030	1
Yb	0.093	31.0	0.038	12.7	0.016	5.3	0.038	12.7	0.043	14.3	0.05	16.7	0.063	21.0	0.003	1
Zn	15	2.0	16.3	2.2	9.5	1.3	15	2.0	19	2.6	11.5	1.6	15.4	2.1	7.4	1
Zr**	15	30.0	24	48.0	7.5	15.0	20	40.0	16	32.0	17	34.0	23.1	46.2	0.50	-
KF		**8.8**		**6.7**		**4.2**		**7.0**		**11.8**		**7.6**		**9.5**		**1**

Note: * Slovak median 2000 (Suchara et al. 2007); **Macedonia (Barandovski et al. 2006); Median Norway value (Steinnes et al. (2001); Aver. -Average; Exc. – exceedance of element concentrations in mosses comparison with Norway (Central Norway belongs to the least polluted regions in Europe); K_F - Coefficient of loading by air pollutants; n- number of Permanent monitoring plots.

Table 2. Atmospheric deposition of elements (average in $mg.m^{-2}.rok^{-1}$) in Báb Research Sites, Vysoké Tatry, Nízke Tatry, Západné Tatry, Slovenský Raj,Veľká Fatra , Slovakia and Norway calculated from concentration of elements in 3 year old segments of *P. schreberi; H. splendens* and *Dicranum* sp. in the year 2000

The examined Slovak territory shows that many regions have intense mining activity. These are characterized by a high concentration of toxic elements such as As, Al, Mn, Cd, Cr, Cu, Hg, Pb, and Sb. The most significant anthropogenic sources are fossil fuels combustion (electric power stations) located in Upper Nitra, and Vojany. Of the other industrial activities, metallurgy, nonferrous ores processing, and cement factories are also important, such as in Central Spiš, Central Pohronie, and Orava. In Slovakia many pollutant sources overlap which causes difficulty in source identification (Maňkovská, 1996; Suchara et al. 2007; Florek et al. 2008).

Sites	Contamination factor K_F					K_F
	< 1	1 -10	10-50	50- 100	>100	
Báb	Au, Br, In, Mg, N, S, Se	Ag, As, Ba,Ca, Cl, Co, Cr, Cs,Cu, Fe,Hg, I, K, Mn, Na, Ni, Rb, Sm, Sr, Ti, U, V, W, Zn	Al, Cd, Ce, La, Mo, Pb, Sb,Sc, Ta, Tb, Th,Yb, Zr	Hf		8.8
Vysoké Tatry	Au, Br, Ca, I, Se	Ag, As, Ba, Cd,Ce, Cl, Co, Cs, Cu, Fe, Hg, In, K, La, Mg, Mn, Mo, N,Na, Ni, Pb, Rb, S, Sc, Se, Sm, Sr, Tb, Th, Ti, U, V, W, Zn	Al, Cr, Sb, Ta, Yb,Zr	Hf		6.7
Nízke Tatry	Au, Br, I, Mg, S, Se, Sm,Ti	Ag, Al, As, Ba, Ca, Cd,Ce, Cl, Co, Cr, Cs, Cu, Fe, Hg, In, K, La, Mn, Mo, N,Na, Ni, Pb Rb, Sb, Sc, Sr, Ta, Tb, Th, U, V, W, Yb, Zn, Zr	Hf			4.2
Západné Tatry	Au, Br,Ca, Hg, I, In, Mg, S,Se, Sm	Ag, Al, As, Ba, Cd,Ce, Cl, Co, Cs, Cu, Fe, K, La, Mn, Mo, N,Na, Ni, Pb Rb, Sc, Sr, Tb, Th, Ti, U, V, W, Zn	Cr, Sb, Yb, Ta, Zr	Hf		7
Slovenský raj	Au, Br, In Sm, Se	Al, As, Ba, Ca, Cd,Ce, Cl, Co, Cr, Cs, Cu, Fe, I, K, La, Mg, Mn, N,Na, Ni, Rb, S, Sc, Sr, Th, Ti, U, V, W, Zn	Ag, Hg, Mo, Pb, Ta, Tb, Yb, Zr	Hf	Sb	11.8
Veľká Fatra	Au, Br,In Sm	Ag, Al, As, Au, Ba, Ca, Cd,Ce, Cl, Co, Cs, Cu, Fe,Hg, I, K, La, Mg, Mn, Mo, N,Na, Ni, Pb Rb, S, Sc, Se, Sr, Ti, U, V, W, Zn	Cr, Sb, Ta, Tb, Th, Yb, Zr	Hf		7.6
Slovakia	Au, Br, In	Ag, As, Ba, Ca, Cd, Cl, Co, Cs, Cu, Fe, Hg, K, La, Mg, Mn, Mo, N,Na, Ni, Rb, S,Sb, Sc, Sm, Sr, Ti, U, V, W, Zn	Al, Ce, Cr, Hf, Pb, Sb, Se, Ta, Tb, Th, Yb, Zr			9.5

Table 3. Coefficient of loading by air pollutants K_F in the year 2000

In comparison with the 1990 survey (Maňkovská, 1997), the average values in 2005 (Fig.1, 2, 3) for Cd, Cr, Cu, Fe, Hg, Ni, Pb, and Zn were reduced. Decreasing concentrations in Slovakia are connected with the decrease in production of steel and non-ferrous metals, and with the fazing out of leaded gasoline.

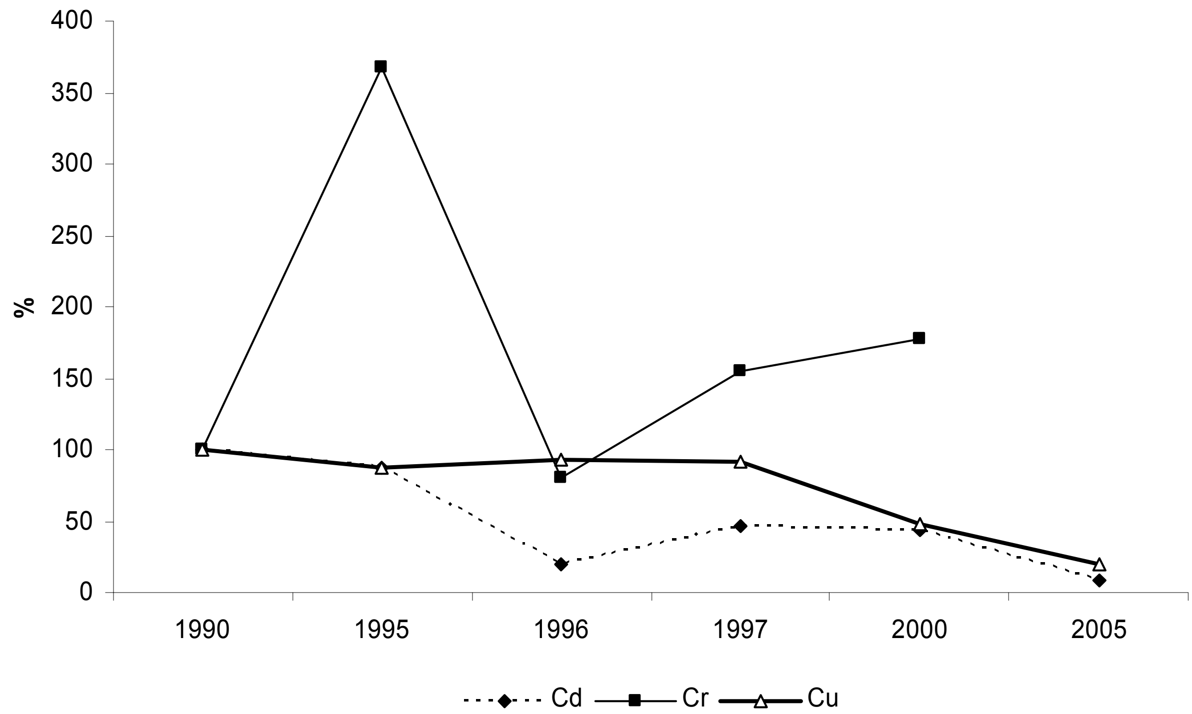

Fig. 1. Concentration of Cd, Cr and Cu (in % of average) in mosses for Slovakia in all survey years
Note: Year (number of PMP): 1990 (58); 1995 (79); 1996 (69); 1997 (74); 2000 (86); 2005 (82)
PMP- Permanent monitoring plots

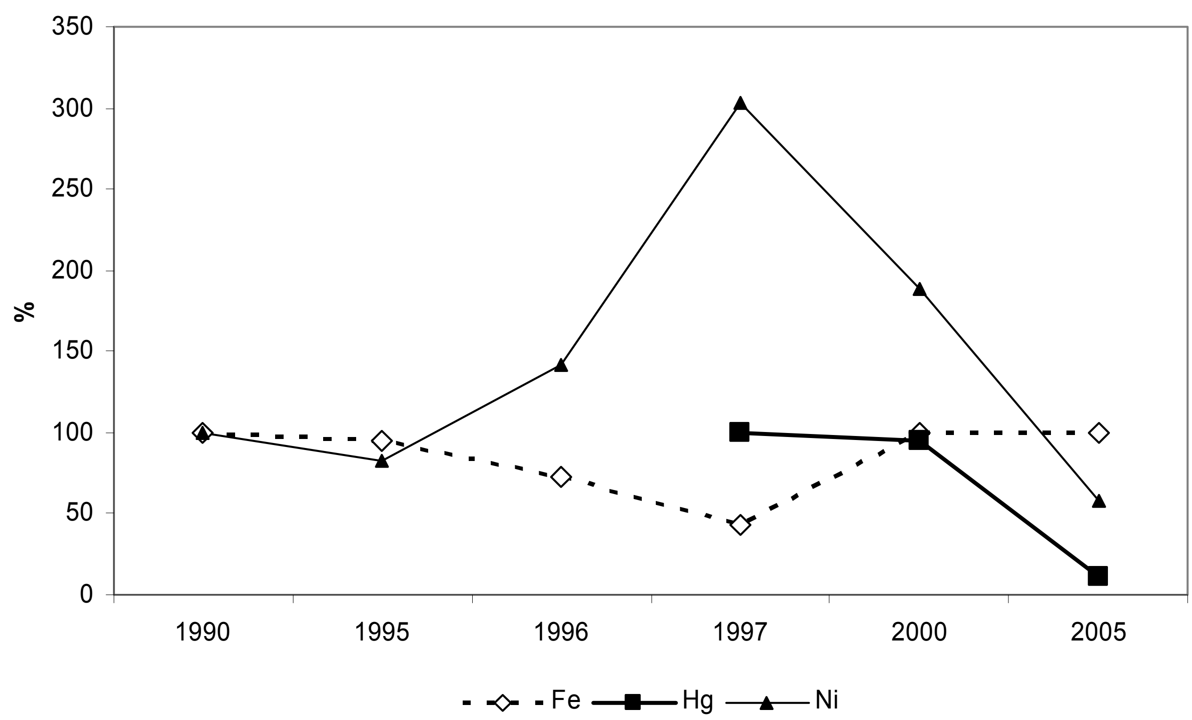

Fig. 2. Concentration of Fe, Hg and Ni (% of average) in mosses for Slovakia in all survey years
Note: Year (number of PMP): 1990 (58); 1995 (79); 1996 (69); 1997 (74); 2000 (86); 2005 (82),
PMP- permanent monitoring plots

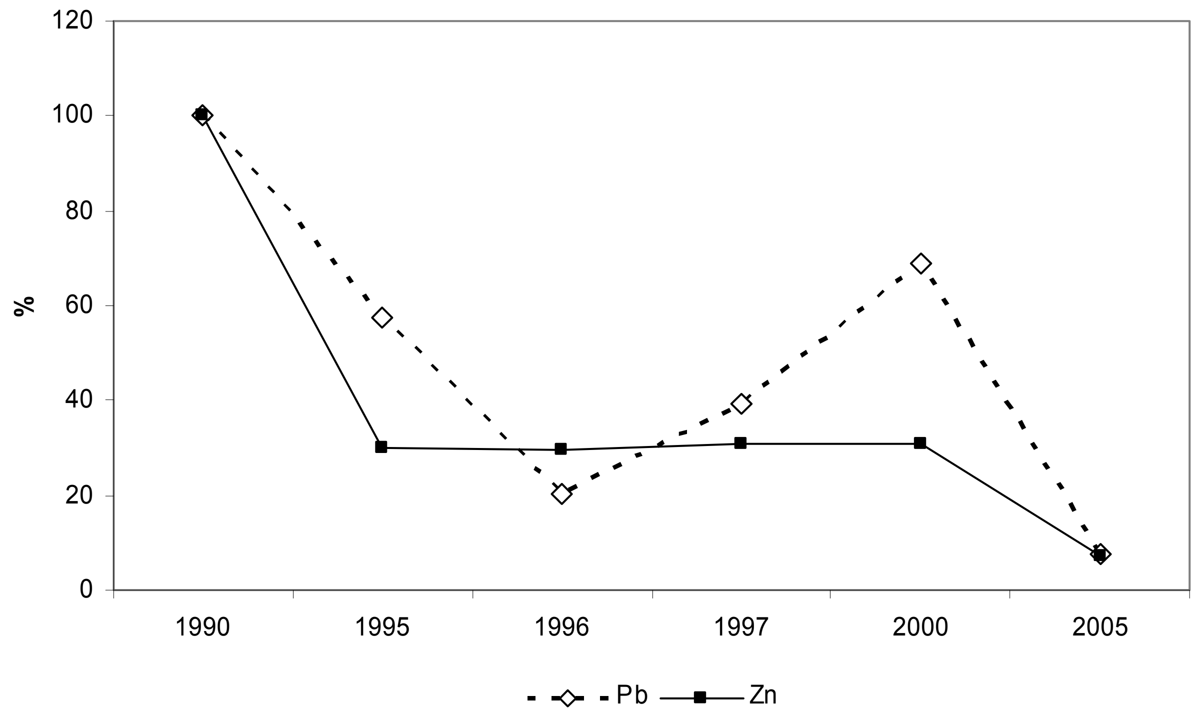

Fig. 3. Concentration of Pb, and Zn (% of average) in mosses for Slovakia in all survey years
Note: Year (number of PMP): 1990 (58); 1995 (79); 1996 (69); 1997 (74); 2000 (86); 2005 (82),
PMP- permanent monitoring plots

This Slovak moss data was subjected to principal component factor analysis (Varimax with Kaiser Normalization). The result of analysis is recorded in Table 4. The 8 factors explain 80% of the total variance in the data set. From the knowledge of the element composition of each factor and the values of factor loadings, the major sources can be identified. Interpretation of 8 factors in the sequence of their significance is as follows:

- Factor 1 is responsible for 40% of the total variance and it is characterized by the presence of all typical crustal elements. It can be explained by elements associated with mineral particles, mainly windblown dust and it includes 13 elements with Al, Sc, Ti, V, Fe, Zr, Re, Hf, Ta, and Th having loadings higher than 0,9, and the next ten elements (Na, Mg, Cr Co, Ni, Se, Sr, Cs, Ba, and U) have loading factors between 0.70–0.89.
- Factor 2 is the industrial component, with very high loadings for Cu, Zn, Ag, Sb, Pb and it is responsible for 10% of the total variance with a factor loading from 0.52 to 0.87. The maximum value is in area of Krompachy – Smolnícka Huta – Zlatá Idka. This factor reflects the impact of metallurgical plants.
- Factor 3 mainly includes Cl, Mn, In and Factor 6 contains K, Rb, and Cs. These elements are likely to be mainly of natural origin.
- Factor 4 includes As, Cd, Pb and S. The pollution with these metals is most likely caused by the lengthy transport. High levels of precipitation are strongly correlated with the heavy metal deposition, and this seems to be main source of heavy metal fallout at higher altitudes.
- Factor 5 has Mo and W elements as its main constituents. Their loading constitutes 0.77 of the factor. The factor components originate from engineering and instrument industry located in the towns of: Brezno, Martin, Dubnica, and Košice and in the triangle Stará Turá–Piešťany–Nové Mesto nad Váhom triangle.

- The major elements in Factor 7 are Ca, I, Br and In. In Slovakia there are 1626 registered mineral water springs of different chemical composition, and a portion of these contain I and Br in adequate quantity.
- Finally, Factor 8 explains 3% of the total variance, where the dominant element is mercury. Sources of contamination with Hg are related to metal processing industries, combustion fossil fuels and municipal solid wastes and trans-boundary contamination in the NW wind directions.

Factor	F1	F2	F3	F4	F5	F6	F7	F8
% of cumulative variability	43,9	53,3	59,8	64,5	68,2	71,4	74,4	76,9
Element								
Ag	0.14	**0.68**	0.15	0.04	0.12	–0.02	–0.20	–0.15
Al	**0.94**	0.06	0.06	0.10	–0.02	0.06	0.18	–0.06
As	0.17	0.36	0.26	**0.61**	0.34	–0.04	0.10	0.16
Au	0.35	0.32	0.43	–0.05	0.24	0.16	0.02	–0.02
Ba	**0.74**	0.35	0.29	–0.01	–0.06	0.16	–0.13	0.01
Br	0.42	–0.12	0.05	0.29	0.24	**0.45**	0.33	0.23
Ca	0.28	–0.03	0.08	0.20	0.07	–0.11	**0.65**	0.11
Cd	0.13	0.21	–0.04	**0.76**	0.14	–0.08	0.12	0.04
Ce	**0.95**	0.08	0.08	–0.06	0.10	0.16	0.01	0.06
Cl	0.08	0.08	**0.82**	0.29	–010	0.20	–0.03	0.14
Co	**0.84**	0.14	0.13	0.01	0.11	–0.04	0.09	0.16
Cr	**0.75**	0.00	0.24	0.26	0.15	–0.12	–0.03	–0.10
Cs	0.59	0.21	0.36	–0.11	–0.10	**0.52**	0.00	0.00
Cu	0.15	0.76	–0.03	0.24	0.17	–0.05	0.22	0.18
Fe	**0.93**	0.14	0.14	0.08	0.04	0.17	0.07	0.02
Hf	**0.92**	0.06	0.11	0.04	–0.03	0.11	–0.03	0.00
Hg	0.01	0.03	0.11	0.05	0.14	–0.06	0.09	**0.85**
I	0.30	0.13	0.10	0.11	0.23	0.05	**0.75**	0.09
In	0.02	0.06	**0.59**	–0.14	–0.14	0.06	0.36	–0.11
K	0.14	–0.03	0.52	0.11	0.21	**0.62**	–0.11	–0.09
La	**0.88**	0.07	0.03	–0.11	0.23	0.22	0.14	0.07
Mg	**0.78**	0.13	0.12	0.22	0.01	0.03	0.37	–0.16
Mn	0.38	0.12	**0.57**	–0.21	0.10	–0.05	0.07	0.20
Mo	0.21	0.21	–0.07	0.26	**0.77**	0.13	0.13	–0.06
Na	**0.80**	0.03	0.03	0.00	0.20	0.13	0.08	–0.17
Ni	**0.84**	0.02	0.09	0.11	0.03	–0.18	0.09	0.12
Pb	0.12	**0.55**	–0.22	**0.51**	0.15	–0.11	0.27	–0.17
Rb	0.28	–0.03	0.08	–0.18	0.10	**0.77**	–0.04	–0.03
S	0.06	0.33	–0.13	0.42	–0.33	0.27	0.18	0.46
Sb	0.09	**0.87**	0.09	0.05	–0.05	0.06	–0.02	0.06
Sc	**0.94**	0.08	0.06	0.01	0.08	0.15	0.16	0.01
Se	**0.85**	0.13	–0.03	0.28	0.17	0.10	0.02	0.04
Sm	**0.88**	0.01	–0.02	–0.06	0.25	0.22	0.10	0.01

Sr	**0.84**	–0.03	0.11	0.20	–0.10	–0.08	–0.06	0.13
Ta	**0.95**	0.08	0.09	0.04	0.04	0.11	0.05	0.01
Tb	**0.94**	0.11	0.05	–0.03	0.12	0.11	0.15	0.09
Th	**0.94**	0.12	0.11	–0.02	0.10	0.19	0.06	0.03
Ti	**0.90**	–0.01	0.03	0.11	0.02	0.00	0.22	–0.02
U	**0.78**	0.10	0.01	–0.05	0.27	0.32	0.24	–0.03
V	**0.90**	0.03	–0.06	0.17	0.09	0.00	0.25	–0.03
W	0.23	0.19	–0.01	0.11	**0.77**	0.13	0.15	0.22
Yb	**0.94**	0.10	0.02	–0.02	0.11	0.09	0.03	0.11
Zn	–0.04	**0.52**	0.22	0.33	0.28	–0.02	0.20	0.14
Zr	**0.93**	0.03	0.10	0.06	0.00	0.09	0.06	–0.05

Note: Eight main source types were identified. Characteristic elements for the sources types are marked in bold type

Table 4. WARIMAX rotated PC analysis of the first eight factors on 86 moss samples collected in the territory of Slovakia in 2000

4. Conclusion

- Mosses provide an effective method for monitoring trends in heavy metals pollution in Slovakia at a high resolution;
- Spatial trends of heavy metal concentrations in mosses were metal-specific. Since 1990, the metal concentration in mosses has declined for cadmium, chromium, cooper, iron, lead, mercury, nickel, and zinc.
- The coefficient of loading by air pollutants K_F for almost all elements is higher than one, excerpt for Au, Br, In, Mg, N, S, Se (Báb); Au, Br, Ca, I, Se (Vysoké Tatry); Au, Br, I, Mg, S, Se, Sm, Ti (Nízke Tatry); Au, Br, Ca, Hg, I, In, Mg, S, Se, Sm (Západné Tatry-Jelenec); Au, Br, In Sm, Se (Slovenský raj) and Au, Br,In Sm (Veľká Fatra), and this is an unfavourable outcome compared to the Norway values. Only the concentration of Au, Br, In, Mg, N, S, Se is lower in Báb Research Sites than relevant Norwegan vakues.
- This obtained data is useful as a reference level for comparison with the future measurements of air pollution in the examined area and also for biodiversity study. Finally, the significance of transboundary atmospheric transport in this region still remains a subject for future study.

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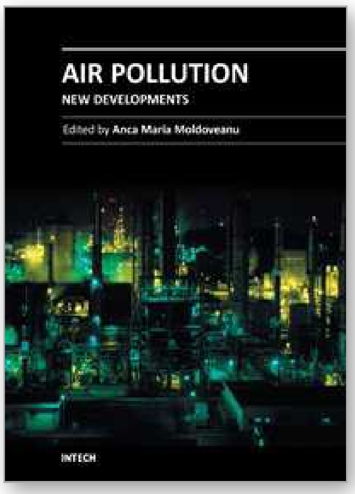

Air Pollution - New Developments

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Today, an important issue is environmental pollution, especially air pollution. Due to pollutants present in air, human health as well as animal health and vegetation may suffer. The book can be divided in two parts. The first half presents how the environmental modifications induced by air pollution can have an impact on human health by inducing modifications in different organs and systems and leading to human pathology. This part also presents how environmental modifications induced by air pollution can influence human health during pregnancy. The second half of the book presents the influence of environmental pollution on animal health and vegetation and how this impact can be assessed (the use of the micronucleus tests on TRADESCANTIA to evaluate the genotoxic effects of air pollution, the use of transplanted lichen PSEUDEVERNIA FURFURACEA for biomonitoring the presence of heavy metals, the monitoring of epiphytic lichen biodiversity to detect environmental quality and air pollution, etc). The book is recommended to professionals interested in health and environmental issues.