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NEW RESULTS FROM AIR POLLUTION STUDIES IN ROMANIA

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1. Introduction

In most European countries, the increased efforts to establish heavy metal monitoring have led to a number of environmental programs at the national and international levels. The moss technique, introduced in the Scandinavian countries about 25 years ago, has shown to be the most suitable for studying the deposition of the heavy metals. It has found numerous applications and is now being widely used for large scale deposition studies.

Matters of environmental protection matter are also being considered most attentively in Romania, especially with respect to the intense local pollution problems resulting from intensive industrial and agricultural activities. In Romania, however, the available resources for the next 10-20 years necessary for the improvement of the environmental conditions are very limited, whereas the cost of attaining certain targets connected with the environment is very high.

For the first time, the moss technique was applied in Romania in 1995 to a systematic study of air pollution with heavy metals and other trace elements in several industrialized and urban areas of the Eastern Romanian Carpathians. This was done to cover one more “white spot” on the heavy metal atmospheric deposition map of Europe. The study has continued later in other regions of Southern and Western Carpathians and most recently in 1999 in the Transilvanian Plateau.

The most important results to be expected by this study are as follows:

- identification of areas with high contamination levels to be considered for the evaluation of environmental risk;
- creation of a database for continued studies at regular intervals;
- establishment of a regional sampling network for future monitoring programs;
- comparison of the environmental contamination levels in Romanian regions with other strongly polluted areas in Europe, such as the “Black Triangle”, the Copper Basin in Poland, the Ural region, etc.

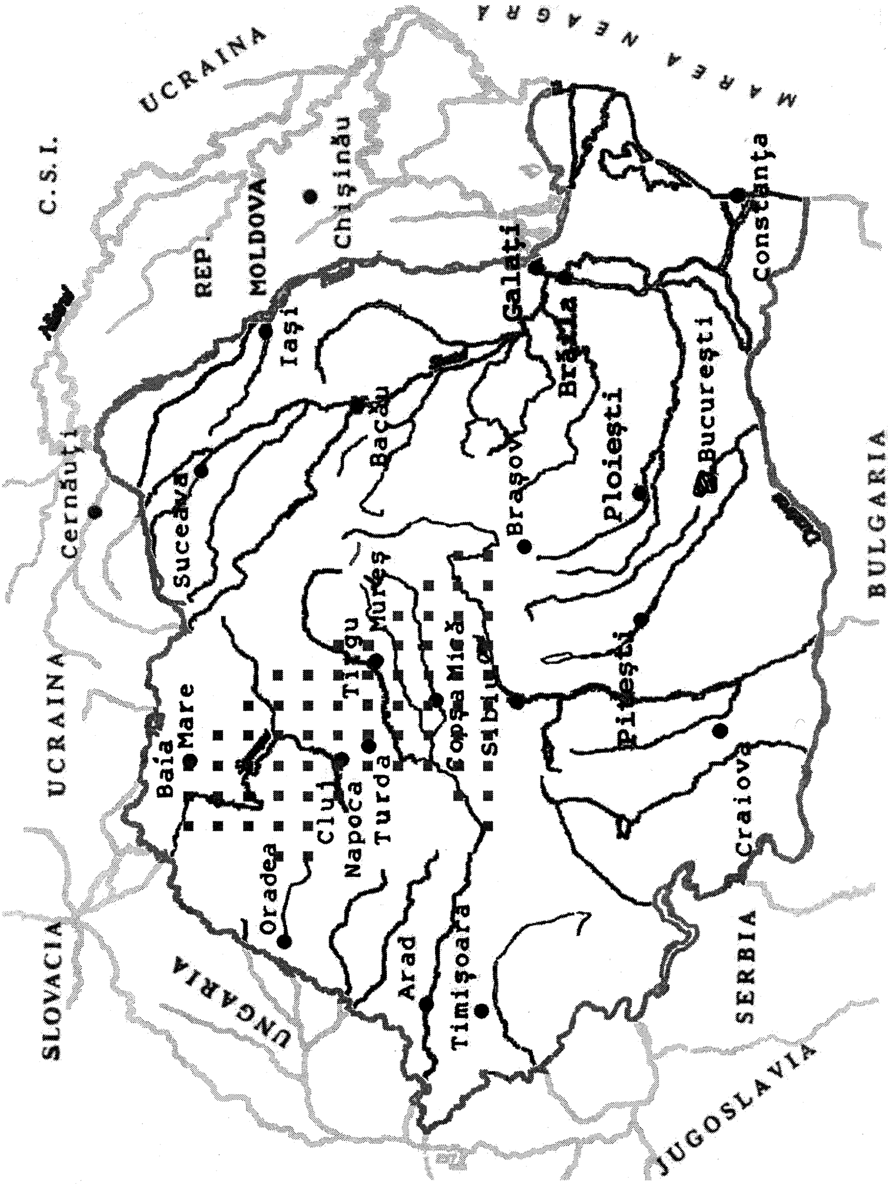
Romania, known for its rich mineral resources, is a highly industrialized country where a great number of metal processing plants as well as coal-fired power plants are operating. The most important metals are iron, chromium, nickel, aluminum, gold, silver, copper and zinc; other important elements are arsenic, mercury, vanadium and rare earth elements. A high concentration of industrial activity is clustered within a limited geographical region in Transilvania. As a result, the environment in the area has reached a state of deep ecological stress. For example, non-ferrous metal processing plants pollute the surroundings of Copsa Mica, Zlatna and Baia Mare with heavy metals such as lead, tin, copper and cadmium, the maximum values of the concentrations exceeding by far the permitted norms [1].

2. Methodology

Study area and sampling

Samples of the moss *Hypnum cupressiforme* were collected during the summer of 1999 according to guidelines described in detail elsewhere [2–4]. The sampling sites **(Fig.1)** were located at least 300 m from main roads and populated areas and at least 100 m from smaller roads or single houses. From each sampling site, 5 to 10 subsamples were taken within a 50 x 50 m area and mixed in the field. The samples were collected with plastic gloves and stored in clean plastic bags. Unwashed green parts of moss plants, cleaned and dried at 40 °C, were taken for analysis. No further homogenization of the samples was performed [5].

Fig1. Sampling sites



Analysis

Moss samples of about 0.3 g were packed in aluminum cups for long-term irradiation and samples of about 0.3 g were heat-sealed in polyethylene foil bags for short-term irradiation. Elements yielding long-lived isotopes were determined using the Cd–screened channel 1 (Ch1) (epithermal neutron activation analysis, ENAA) at the IBR-2 reactor in Dubna, Russia. Samples were irradiated for 5 days, re–packed, and then measured twice after 4–5 and 20 days of decay, respectively. Measurement time varied from 1 to 5 hours. To determine the short–lived isotopes of Na, Mg, Al, Cl, K, Ca, Mn, I, and Br (^{80}Br), channel 2 (Ch2) was used (conventional NAA). Samples were irradiated for 5 min and measured twice after 3-5 min of decay for 5-8 and 20 min, respectively.

Table 1. Characteristics of the irradiation channels

Irradiation site	$\Phi_{th}\cdot10^{12}$, n/s·cm^2, E= 0 ÷ 0.55 eV	$\Phi_{res}\cdot10^{12}$, n/s·cm^2, E= 0.55 ÷ 10^5 eV	$\Phi_{fast}\cdot10^{12}$, n/s·cm^2, E= 10^5 ÷$25\cdot10^6$ eV
Ch1 (Cd-screened)	0.023	3.31	4.32
Ch2	1.23	2.96	4.10

Data processing and element concentration determinations were performed on the basis of certified reference materials and flux comparators, using software developed in FLNP JINR [6]. For long-term irradiation in Ch1, single comparators of Au (1μg) and Zr (10 μg) were used. For short-term irradiation in Ch2 a comparator of Au (10 μg) was employed. Concentrations of elements yielding long–lived isotopes were also determined using certified reference materials: SDM sediment (International Atomic Energy Agency, Vienna), Montana Soil (NIST) and moss DK-1, prepared for calibration of laboratories participating in the corresponding 1990 Nordic survey [7]. Interference from the ^{56}Fe(n,p)^{56}Mn and ^{54}Fe(n,p)^{51}Cr reactions was estimated at less than 0.1% for the given concentrations of Fe. The high density of fast neutrons in the irradiation channels used provided favourable conditions for the determination of Ni by the ^{58}Ni(n,p)^{58}Co reaction. However, problems with interfering nuclear reactions are evident in a number of instances, as shown in **Table 2.**

Table 2. Interference by fast neutron reactions*

Intended reaction	Interfering reaction	Level of interference/ng **
^{23}Na(n,γ)^{24}Na	^{24}Mg(n,p)^{24}Na	3 x 10^5
	^{27}Al(n,α)^{24}Na	1.5 x10^6
^{26}Mg(n,γ)Mg^{27}	^{27}Al(n,p)^{27}Mg	9 x10^8
^{27}Al(n,γ)^{28}Al	^{28}Si(n,p)^{28}Al	3 x 10^7
	^{31}P(n,α)^{28}Al	9 × 10^6
^{41}K(n,γ)^{42}K	^{42}Ca(n,p)^{42}K	—†
	^{45}Sc(n,α)^{42}K	1.5 × 10^6
^{51}V(n,γ)^{52}V	^{52}Cr(n,p)^{52}V	1 x 10^4
^{50}Cr(n,γ)^{51}Cr	^{54}Fe(n,α)^{51}Cr	4 x 10^5
^{55}Mn(n,γ)^{56}Mn	^{56}Fe(n,p)^{56}Mn	7 x 10^4
^{58}Fe(n,α)^{59}Fe	^{59}Co(n,p)^{59}Fe	2.3 x 10^8
^{63}Cu(n,γ)^{64}Cu	^{64}Zn(n,p)^{64}Cu	5 x 10^6

* Cr and Fe were determined in Ch 1, all other elements mentioned here in Ch2 (see **Table 1**).

** As compared with 1 gram of the interfering element.

† Cross–section not available.

3. Results and discussion

The results obtained for the Transilvanian Plateau are shown in **Table 3**, in comparison with other relevant areas from Russia (Ural), Poland (Copper Basin) and Norway (Mo, local ferrochrome smelter).

Polymetallic mining industries have polluted a vast territory with Fe, Pb, Cr, etc. Non-ferrous metal industries in Copsa Mica, Zlatna, and Baia Mare are responsible for pollution with elements such as Pb, Cu, and Cd. The iron and steel factories of Hunedoara and Calan show emissions of iron and non-ferrous metals.

From **Table 3** the following observations can be made regarding the concentrations of metals such as As, Cr, Cu, Fe, Mg, Mn, Ni, Pb and Zn:

- in Transilvanian Plateau the concentrations of these elements exceed the values from Russia, Poland and Norway; very serious is the fact that As, Cu, Pb and Zn show concentrations about ten times greater in Romania;
- the concentrations of Mg, Cr and Mn in Romania, Poland and Norway are comparable and lower than in the South Ural Mountains (Russia);
- the Ni concentration is lower in Romania that in the other areas

A correlation coefficient matrix (**Table 4**) shows the inter-elemental relationships between pairs of elements in moss. Good correlations between some elements indicate a common source or identical behaviour during long range atmospheric transport. Representative graphs for some inter-element correlations are shown in **Fig. 2 and Fig 3**. Most of these correlations represent pollution one way or another. Exceptions are the pairs Ti-Al, V-Al, Co-Fe, Ta-Th, and Th-Sc, which probably express geochemical similarities of these elements in soil particles attached to the moss samples.

The results of factor analysis are given in **Table 5**. Preliminary assessment of factors could be assumed as follows: factors 1-2: soil (crustal components); factors 3-4: pollution; factor 5: soil again.

A graphical technique developed for aerosols, [14] for extracting the elemental compositions of the crustal, marine, and general pollution components and proved to be efficient for lichens [15] was successfully applied to Transilvanian moss samples.

The moss-crust enrichment factor of an element X is defined as

$$EF_{crust}=(X/Sc)_{moss}/(X/Sc)_{crust}$$

where Sc is the usual crustal reference element and the dominator $(X/Sc)_{crust}$ is the ratio of the X and Sc in the crustal reference material. It is evident that enrichment factors for "crustal" elements fall within factors of three or so of unity and signify that those elements have come from the crust (either directly as windblown soil or indirectly as coal fly ash). Enrichment factors for other elements lie well above unity, and in our case are to be found between 10^2-10^3. These "enriched" elements are noncrustal in origin (**Fig. 4**).

Potential best indicators of non-crustal origin can be distinguished by comparison of moss average composition with that of atmospheric aerosol or deposition. **Fig. 5** does this by showing enrichment factors of the average moss relative to average urban aerosol [16], where the enrichment factor X is defined as

$$EF=(X/Sc)_{moss}/(X/Sc)_{urban\ aerosol}$$

Potential best indicators of deposition as follows from **Fig. 5** Cl, V, Ni, Se, Br, Sb, Cs.

Table 3. Element concentration (*ppm*) in moss from Transilvanian Plateau (Romania) and in some other relevant areas used for comparison

Element	Transil. Plateau (Romania)		Ural (Russia)[8]		Copper Basin (Poland)[9]		Tula (Russia) [10]		Mo (Norway) [11]		Norway [12,13] background level
	Mean	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Na	1025	192- 4329	394	174 – 1051	152	74-302	403	147-882	294	93-635	200
Mg	2931	480- 6842	5003	1353 – 15400	1694	800-6480	2878	1160-4982	1861	556-4230	1200
Al	6349	827-23010	2819	810 – 7000	815	237-2590	2486	402-6015	1244	243-3100	350
Cl	434	161- 1311	314	44 – 1114	226	113-537	859	232-2521	294	50-1110	200
K	8700	4470- 20000	6842	2642 – 13260	5005	515-8708	19628	8910-42230	3845	1930-7160	3000
Ca	6623	1248-23500	5093	2030 – 13800	2229	1190-12800	7260	3290-12380	2871	1450-6740	1500
Sc	1.42	0.213- 6,13	0.60	0.10 – 1.45	0.15	0.03-0.63	0.39	0.09-1.19	0.41	0.06-1.41	0.06
V	9.79	1.95-32	8.50	2.0 – 22.4	2.60	1.14-8.13	11.2	1.38-62	5.72	1.05-31.0	2
Cr	15.7	2.72- 51.9	18.6	2.2 – 194	1.43	0.80-3.16	2.95	0.88-9.6	11.7	0.5-50	1.5
Mn	322	27- 1471	344	88 – 1402	287	65-847	391	100-817	384	89-1460	200
Fe	4343	815- 21340	1888	335 – 7438	520	219-1405	3030	471-19670	12280	700-72100	400
Co	1.89	0.31- 7.05	0.64	0.14 – 1.95	0.32	0.11-1.96	0.13	0.05-0.29	0.61	0.06-2.2	0.3
Ni	6.84	0.58- 32	8.4	0.96 – 94	2.49	0.21-38	0.53	0.21-1.21	1.69	<0.5-6.96	1.6
Cu	199	18- 2423	34	5 – 200	73	3.11-2040					
Zn	291	39.2- 2946	72	14.8 – 304	41	21-83	69	27.15-105	99	31-397	36
As	8.4	0.594- 119	2.17	0.63 – 9.7	0.73	0.12-6.04	0.51	0.11-1.47	0.62	0.06-2.20	0.3
Se	0.699	0.0754- 5.01	0.34	0.02 – 1.1	0.32	0.10-0.77	0.13	0.05-0.20	0.47	0.21-1.17	0.25
Br	8.69	2.03- 21	6.20	1.52 – 25	1.38	0.89-2.85	4.05	1.44-12.7	6.94	3.6-12.2	5
Rb	20.3	5.76- 135	10.3	2.8 – 39	21	1.95-45.51	19	6.2-32	17.2	6.7-46.2	10
Sr	47.3	1.84- 289	18	1.96 – 65	12.4	0.69-339					
Mo	1.523	0.132- 14.6	0.29	0.041 – 0.71	0.29	0.05-2.42					
Ag	0.684	0.0326- 4.54	0.124	0.011 – 0.47	0.12	0.02-1.74	0.06	0.02-0.15	0.059	<0.03-0.16	0.04
Cd	3.99	0.275-55	0.63	0.16 – 2.86	0.30	0.03-1.07					
Sb	4.72	0.160- 51	2.63	0.08 – 29	0.26	0.12-0.79	0.13	0.05-0.7	0.25	<0.05-0.76	0.09
I	2.28	0.795- 5.55	1.35	0.51 – 3.41	1.14	0.35-2.68	1.58	0.51-4.3	2.26	<1.0-4.3	2
Cs	0.65	0.122- 3.40	0.22	0.04 – 0.61	0.43	0.08-1.29	0.20	0.06-0.48	0.37	<0.05-1.03	0.18
Ba	116	21.6- 658	44	6.3 – 125	13.6	5.47-79	65	10-145	33.1	12.0-83.0	24
La	3.31	0.362- 5.06	2.43	0.47 – 13	0.52	0.14-1.61	2.40	0.42-6.75	0.69	<0.10-2.87	0.3
Ce	4.44	0.930- 18.4	3.24	0.53 – 11.7	1.27	0.24-3.74	3.45	0.64-10.9			-
Sm	0.546	0.008- 2.51	0.29	0.07 – 1.05	0.13	0.06-0.63	0.40	0.08-1.05	0.33	0.05-1.34	0.06
Tb	0.105	0.006- 0.419	0.035	0.004 – 0.17	0.01	0.003-0.09	0.04	0.008-0.126	0.019	<0.005-0.067	0.015
Yb	0.327	0.033- 1.48	0.107	0.005 – 0.55	0.04	0.01-0.18	0.13	0.028-0.38	0.069	<0.010-0.230	0.03
Hf	0.794	0.122- 4.66	0.276	0.023 – 1.78	0.13	0.01-0.58	0.45	0.08-1.51	0.179	<0.04-0.71	0.05
Ta	0.148	0.0134- 0.661	0.045	0.004 – 0.48	0.02	0.004-0.13	0.04	0.01-0.13	0.043	<0.003-0.180	0.005
W	1.725	0.115- 8.74	0.34	0.06 – 1.27	0.17	0.02-0.62	0.14	0.05-0.40	1.71	<0.6-6.4	-
Au	0.034	0.00331- 0.135	0.011	0.002 – 0.086	0.005	0.0004-0.02	0.02	0.005-0.067	0.0002	<0.0001-0.010	-
Th	1.237	0.219- 4.70	0.36	0.054 – 1.72	0.13	0.05-0.45	0.47	0.095-1.46	0.267	0.04-1.10	0.08
U	0.354	0.0419- 1.358	0.15	0.057 – 0.73	0.10	0.02-0.99	0.18	0.052-0.59	0.143	<0.03-0.51	0.05

Table 4. Correlation coefficient matrix of moss from Transilvanian Plateau

	Na	Mg	Al	Sc	Ti	V	Cr	Fe	Co	Ni	Cu	Zn	As	Se	Rb	Sr	Zr	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Sm	Tb	Hf	Ta	W	Au	Th	U
Na	1.00																																
Mg	0.49	1.00																															
Al	0.68	**0.75**	1.00																														
Sc	**0.70**	0.42	0.65	1.00																													
Ti	0.66	**0.70**	**0.92**	**0.70**	1.00																												
V	0.64	**0.72**	**0.93**	0.64	**0.86**	1.00																											
Cr	0.66	0.36	0.61	**0.76**	0.64	0.57	1.00																										
Fe	0.61	0.27	0.48	**0.88**	0.52	0.53	**0.76**	1.00																									
Co	0.66	0.39	0.58	**0.90**	0.64	0.53	**0.76**	**0.90**	1.00																								
Ni	0.48	0.30	0.48	**0.84**	0.49	0.51	0.69	**0.75**	**0.77**	1.00																							
Cu	0.13	0.05	0.10	0.11	0.12	0.18	0.08	0.43	0.33	0.01	1.00																						
Zn	0.16	-0.15	-0.07	0.22	-0.05	-0.02	0.25	0.48	0.35	0.14	0.53	1.00																					
As	0.21	-0.05	0.00	0.11	0.04	0.05	0.12	0.44	0.33	0.01	**0.93**	0.59	1.00																				
Se	0.20	-0.17	0.00	0.40	0.06	0.07	0.42	**0.71**	0.55	0.37	0.69	**0.73**	**0.73**	1.00																			
Rb	0.42	0.13	0.32	**0.84**	0.42	0.37	0.68	**0.88**	**0.78**	**0.80**	0.20	0.35	0.21	0.65	1.00																		
Sr	0.14	-0.07	-0.01	0.42	-0.01	0.07	0.42	0.66	0.46	0.52	0.30	0.60	0.33	0.69	0.68	1.00																	
Zr	0.30	0.05	0.22	**0.73**	0.30	0.31	0.59	**0.85**	0.66	0.69	0.29	0.44	0.30	**0.71**	**0.91**	**0.78**	1.00																
Mo	0.14	-0.07	0.00	0.11	0.04	0.08	0.11	0.46	0.31	-0.01	**0.94**	0.56	**0.95**	**0.75**	0.26	0.36	0.35	1.00															
Ag	0.24	0.03	0.07	0.46	0.15	0.11	0.33	0.65	0.56	0.37	0.61	0.66	0.64	**0.83**	0.63	0.52	0.61	0.64	1.00														
Cd	0.22	-0.08	-0.04	0.05	-0.04	-0.03	0.13	0.19	0.15	-0.06	0.31	**0.87**	0.40	0.41	0.03	0.26	0.08	0.31	0.41	1.00													
Sn	0.02	-0.18	-0.03	0.39	0.01	0.11	0.34	0.68	0.42	0.37	0.50	0.61	0.45	**0.80**	0.67	**0.78**	**0.83**	0.57	0.63	0.21	1.00												
Sb	0.12	-0.20	-0.11	0.22	-0.06	-0.03	0.25	0.53	0.37	0.13	0.63	**0.95**	0.68	**0.84**	0.43	0.60	0.51	0.69	**0.75**	**0.76**	**0.70**	1.00											
Cs	0.63	0.36	0.58	**0.96**	0.62	0.58	**0.77**	**0.87**	**0.85**	**0.86**	0.07	0.22	0.06	0.46	**0.87**	0.54	**0.78**	0.08	0.45	0.02	0.46	0.22	1.00										
Ba	0.36	0.15	0.30	**0.79**	0.38	0.32	**0.71**	**0.79**	**0.72**	**0.77**	0.03	0.32	0.04	0.51	**0.87**	**0.72**	**0.86**	0.06	0.44	0.05	0.58	0.34	**0.82**	1.00									
La	**0.79**	0.59	0.69	**0.73**	**0.73**	0.57	0.60	0.50	**0.70**	0.50	-0.03	-0.07	-0.01	0.00	0.40	-0.10	0.15	-0.08	0.16	0.03	-0.17	-0.09	0.62	0.35	1.00								
Sm	**0.70**	0.60	**0.71**	0.64	**0.77**	0.58	0.52	0.39	0.62	0.43	-0.04	-0.21	-0.08	-0.10	0.31	-0.20	0.10	-0.12	0.06	-0.10	-0.25	-0.21	0.54	0.28	**0.87**	1.00							
Tb	**0.73**	0.48	0.67	**0.97**	**0.74**	0.61	**0.73**	**0.82**	**0.91**	**0.77**	0.10	0.17	0.10	0.33	**0.76**	0.30	0.61	0.08	0.43	0.06	0.26	0.18	**0.89**	0.28	**0.84**	**0.76**	1.00						
Hf	0.59	0.30	0.52	**0.95**	0.62	0.53	**0.73**	**0.90**	**0.87**	**0.79**	0.21	0.30	0.21	0.55	**0.90**	0.55	**0.87**	0.23	0.55	0.05	0.56	0.34	**0.93**	**0.86**	0.56	0.52	**0.89**	1.00					
Ta	**0.70**	0.52	0.69	**0.90**	**0.77**	0.58	0.67	0.66	**0.84**	**0.71**	-0.02	0.00	-0.03	0.15	0.63	0.11	0.45	-0.06	0.29	-0.04	0.06	-0.01	**0.82**	0.61	**0.89**	**0.84**	**0.96**	**0.81**	1.00				
W	0.56	0.37	0.41	0.40	0.39	0.29	0.48	0.30	0.52	0.31	-0.11	-0.17	-0.09	-0.08	0.17	-0.13	-0.03	-0.14	-0.02	-0.05	-0.24	-0.17	0.36	0.17	0.67	0.66	0.49	0.29	0.57	1.00			
Au	0.10	-0.07	-0.06	0.00	-0.04	0.01	0.03	0.32	0.20	-0.03	**0.82**	0.56	**0.83**	0.68	0.20	0.37	0.25	**0.87**	0.65	0.35	0.45	0.66	-0.01	0.00	-0.15	-0.20	-0.02	0.11	-0.15	-0.15	1.00		
Th	0.69	0.44	0.65	**0.98**	**0.71**	0.64	**0.74**	**0.87**	**0.88**	**0.79**	0.12	0.19	0.12	0.36	**0.81**	0.38	**0.71**	0.12	0.41	0.03	0.36	0.20	**0.92**	**0.76**	**0.73**	0.66	**0.96**	**0.94**	**0.89**	0.39	-0.01	1.00	
U	**0.85**	0.58	**0.72**	**0.74**	**0.75**	0.64	0.62	0.57	**0.74**	0.53	0.12	-0.04	0.11	0.07	0.43	-0.03	0.24	0.07	0.18	0.01	-0.08	-0.04	0.65	0.36	**0.89**	**0.88**	**0.81**	0.62	**0.85**	**0.71**	-0.01	**0.87**	1.00

Fig. 2 Inter-element correlations for Transilvanian moss

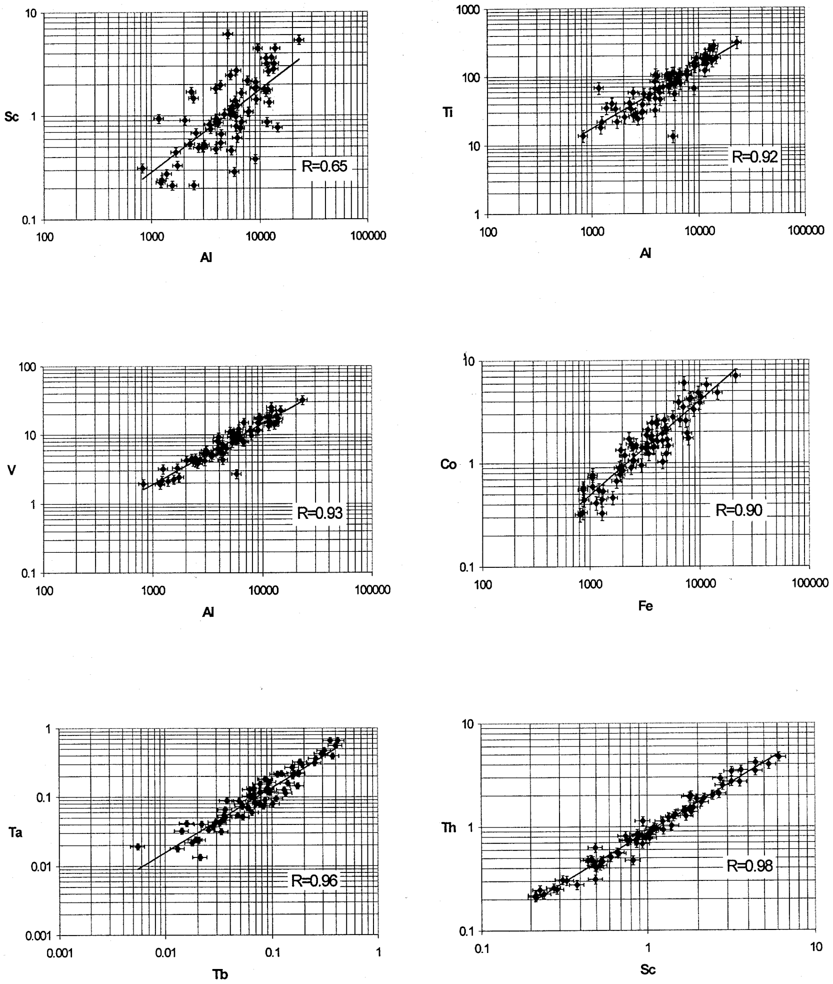


Fig. 3 Inter-element correlations for Transilvanian moss

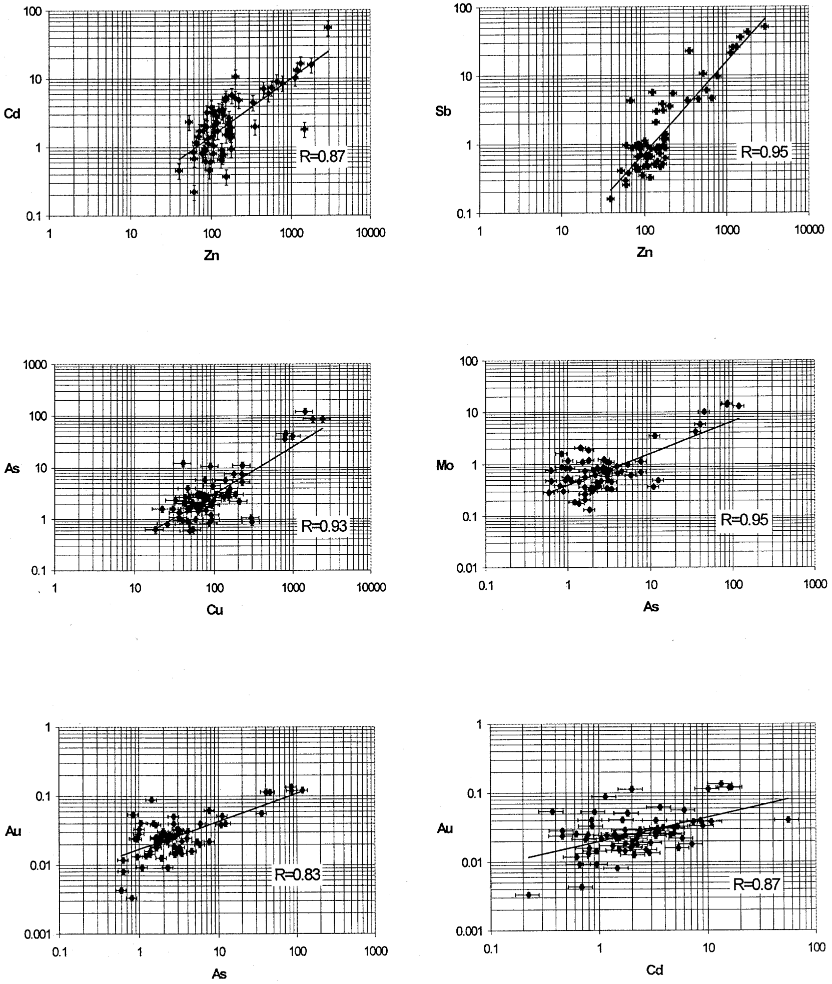


Fig. 4 Enrichment factors of elements in Transilvanian moss with respect to crust

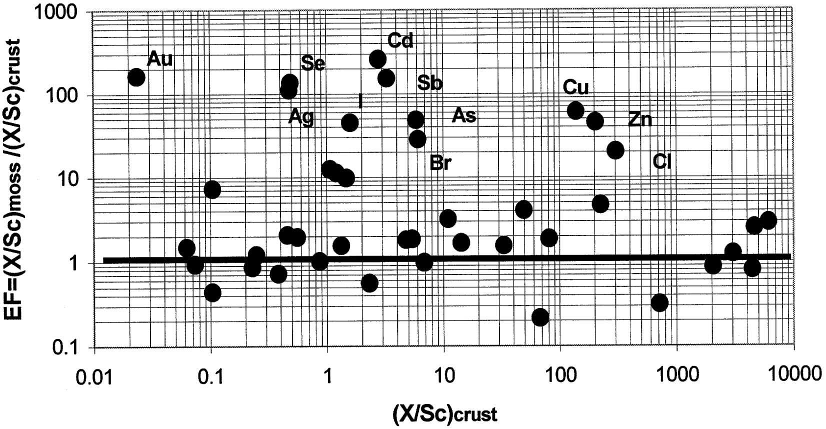


Fig. 5 Enrichment factors of elements in Transilvanian moss with respect to urban aerosol

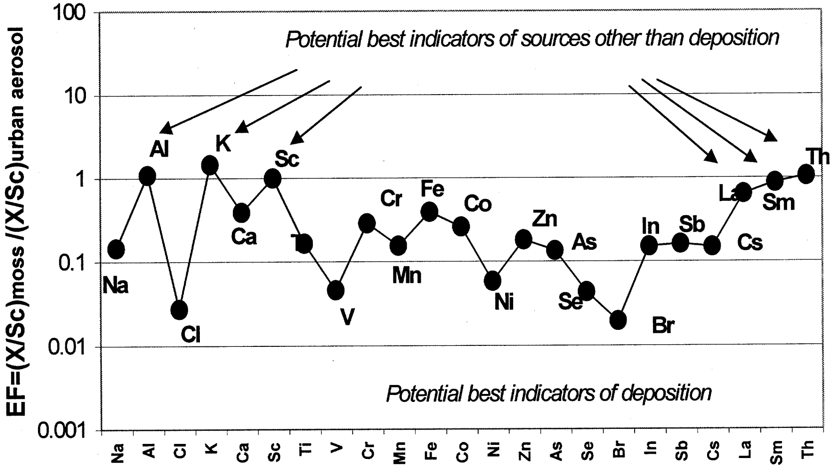


Table 5

Rotated Component Matrix

	Component					
	1	2	3	4	5	6
NA	0.24	**0.76**	0.07	0.34	-0.01	0.23
MG	0.02	**0.81**	-0.07	-0.12	0.31	-0.04
AL	0.20	**0.89**	-0.04	-0.05	0.12	-0.04
CL	-0.07	-0.06	0.01	0.18	**0.83**	0.14
K	0.18	0.41	-0.02	**0.77**	0.21	-0.07
CA	-0.06	-0.11	0.33	0.01	**0.64**	0.08
SC	**0.75**	0.61	0.03	0.10	-0.13	0.06
V	0.26	**0.81**	0.02	-0.08	0.24	-0.08
CR	**0.63**	0.50	0.01	0.22	-0.04	0.13
MN	0.22	0.57	0.18	-0.08	-0.09	0.14
FE	**0.79**	0.40	0.37	0.13	-0.04	0.05
CO	**0.66**	0.58	0.27	0.13	-0.19	0.09
NI	**0.79**	0.38	-0.06	-0.03	-0.03	0.18
CU	0.03	0.12	**0.96**	-0.02	0.06	-0.05
ZN	0.32	-0.15	0.55	**0.70**	0.08	-0.12
AS	0.04	0.05	**0.94**	0.14	0.01	-0.01
SE	0.58	-0.11	**0.72**	0.23	-0.01	0.03
BR	0.26	0.13	-0.15	-0.06	0.05	**0.79**
RB	**0.92**	0.20	0.18	0.02	-0.08	0.07
SR	**0.78**	-0.22	0.27	0.20	0.34	0.11
ZR	**0.94**	0.05	0.26	0.00	0.03	-0.08
MO	0.10	0.01	**0.96**	0.03	0.04	-0.05
AG	0.48	0.05	**0.68**	0.22	0.03	0.02
CD	-0.02	-0.03	0.32	**0.89**	0.03	-0.09
SB	0.36	-0.18	**0.68**	0.55	0.01	-0.11
I	0.06	0.23	0.06	-0.12	0.16	**0.75**
CS	**0.82**	0.49	0.00	0.08	-0.04	0.15
BA	**0.92**	0.15	-0.02	0.07	-0.03	0.14
LA	0.19	**0.85**	-0.09	0.17	-0.30	0.18
CE	0.40	**0.75**	-0.10	0.02	-0.33	0.15
SM	0.12	**0.86**	-0.12	-0.01	-0.28	0.10
HF	**0.84**	0.45	0.15	0.04	-0.14	0.00
AU	0.03	-0.06	**0.88**	0.10	0.23	0.04
TH	**0.72**	**0.63**	0.04	0.07	-0.17	0.02
U	0.21	**0.87**	0.04	0.10	-0.19	0.21

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization
Rotation converged in 7 iterations.

In the following text the elements studied area discussed with regard to the observed spatial trends as influences by long range atmospheric transport, deposition of pollutants from local point sources, etc. The locations of point sources of heavy metal pollution are mentioned in the text.

Aluminium

The Al concentrations observed in moss are most probably explained by contribution from local soil material (mainly windblown dust). This assumption is in agreement with the conclusion from the principal component analysis carried out. All Al values were between 828 *ppm* and 23010 *ppm*, with a median of 5411 *ppm*, which is very high compared to values observed in northern Europe and strongly suggesting a generally significant soil contamination of the moss samples.

Iron

The Fe concentration in moss is explained by the soil factor, as indicated e.g. by the high Fe-Sc correlation. The lower correlation in Luncani region is caused by major emission from the wirework industry. The Fe values range from 800 ppm to 21000 ppm, the median being 340 ppm.

Antimony

The highest levels of Sb were found in Cergau close to one of the most important center of non-ferrous metal industry of Romania. The Sb values of all samples analyzed range from 0.16 *ppm* to 50 *ppm,* the median being 0.92 *ppm.* Similar situation was observed for the South Ural Mauntains [8].

Selenium

Se is typical for all copper deposits, due to its presence in ore forming sulphides . A second source of Se could be Pb - Zn deposits. The Se values were between 0.075 *ppm* and 5.0 *ppm*, with a median of 0.37 *ppm.*

Arsenic

Strongly elevated arsenic levels were found in the northern part of Transilvania (Zagra, Letca, Magoaja) where there is a long tradition of ore mining and in the Baia Mare region which is affected by the non-ferrous metal industry. All arsenic values in this investigation were between 0.59 *ppm* and 118 *ppm*, with a median of 2.3 *ppm.*

Zinc

Two regions with high Zn concentration were distinguished. One of them is Cergau, where there is a Zn and Pb smelter. The second is Letca – Magoaja – Ileanda, characterized by non-ferrous ore mining. The Zn values were between 39 *ppm* and 2900 *ppm*, median being 137 *ppm*.

Copper

Copper showed the highest concentration in the same region as arsenic and has the same source, ore mining and non-ferrous metal industry. All Cu values range between 18 *ppm* and 2400 *ppm*, the median being 73 *ppm*.

Cadmium

The high cadmium concentration in Cergau region is mainly due to Zn and Pb smelters. Moreover, the pattern of Cd distribution showed increased concentrations in Zagra – Letca - Magoaja region, probably a result of ore mining. A high Cd concentration level observed in Aiud may be explained by the presence of an oil-fired power station without proper filters. All Cd values were between 0.23 *ppm* to 55 *ppm*, with a median of 1.99 *ppm*.

The average life expectancy in Romania is one of the lowest in Europe: 66.56 years for men and 73.17 years for women.The serious air pollution situation is likely to be one of the factors responsible for these unfortunate health conditions. In the period after 1989, and especially during the last three years extensive measures have been taken in order to improve the environmental conditions in Romania. The results from the present work however show that there is still a long way to go.

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Стан О.А. и др. E14-2000-126
Новые результаты по атмосферным загрязнениям в Румынии

Сообщаются результаты выполнения следующего этапа проекта «Изучение атмосферных выпадений тяжелых металлов в сельскохозяйственных и промышленных районах Румынии с помощью мхов биомониторов и ядерно-физических методов анализа» по координационной программе Международного агентства по атомной энергии (Вена, Австрия). Семьдесят образцов мха *Hypnum Cupressiforme* были собраны в наиболее загрязненных районах северо-восточной части Трансильвании летом 1999 г. Эпитепловой нейтронный активационный анализ этих образцов проводился на реакторе ИБР-2 ЛНФ ОИЯИ, Дубна. Контроль качества измерений обеспечивался применением стандартов МАГАТЭ. В результате был определен широкий круг элементов, включая тяжелые металлы и редкоземельные элементы (Na, Mg, Al, Cl, K, Ca, Sc, V, Cr, Mn, Fe, Co, Ni ((n,p)-реакция), Cu, Zn, As, Se, Br, Rb, Sr, Zr, Mo, Ag, Sn, Sb, I, Cs, Ba, La, Ce, Nb, Sm, Eu, Gd, Tb, Hf, Ta, W, Au, Th, U). Были определены пятна атмосферных выпадений тяжелых металлов на региональном уровне. По аналогии с другим «грязным» регионом, Южным Уралом, в румынском городе Чергау была выявлена высокая концентрация сурьмы, достигающая в максимуме 50 ppm. Полученные результаты согласуются с исследованиями атмосферных выпадений тяжелых металлов, которые проводились в Румынии ранее, а также с аналогичными исследованиями в Германии, Нидерландах, Польше, России и других странах.

Работа выполнена в Лаборатории нейтронной физики им. И.М.Франка ОИЯИ.

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Stan O.A. et al. E14-2000-126
New Results from Air Pollution Studies in Romania

Results from the next stage of the project «Atmospheric Deposition of Heavy Metals in Rural and Urban Areas of Romania Studied by the Moss Biomonitoring Technique Employing Nuclear and Related Analytical Techniques», carried out under the auspieces of the International Atomic Energy Agency, Vienna, are reported. A total of 70 moss samples (*Hypnum Cupressiforme)* were collected from highly polluted areas in the north-eastern part of Transylvania during the summer of 1999. The samples were analyzed by epithermal neutron activation analysis at the pulsed fast reactor IBR-2 at JINR, Dubna, for a wide range of elements including heavy metals and rare earths (Na, Mg, Al, Cl, K, Ca, Sc, V, Cr, Mn, Fe, Co, Ni ((n,p) reaction), Cu, Zn, As, Se, Br, Rb, Sr, Zr, Mo, Ag, Sn, Sb, I, Cs, Ba, La, Ce, Nb, Sm, Eu, Gd, Tb, Hf, Ta, W, Au, Th, and U). IAEA certified reference materials were used to ensure the quality of the measurements. The regional extent of pollution patterns of specific metals was determined. Like another strongly polluted area — the South Ural Mountains — concentrations of Sb as high as 50 ppm were observed in the vicinity of Cergau in Romania. The results reported are consistent with those obtained in the previous moss-surveys in Romania and also with studies carried out in Germany, the Netherlands, Poland, Russia and other countries.

The investigation has been performed at the Frank Laboratory of Neutron Physics, JINR.

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