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NEW RESULTS FROM AIR POLLUTION STUDIES IN BULGARIA (MOSS SURVEY 2000–2001)

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Introduction

The survey of world-wide emissions of toxic heavy metals into the atmosphere shows that the anthropogenic impact on the environment during the last years is becoming a decisive factor in the global cycle of many elements. The knowledge of atmospheric deposition of heavy elements is of a vital concern in countries such as Bulgaria where the economy depends strongly on the export of agricultural products. The small territory of Bulgaria is affected by different pollutants: the coal burning in coal-fired power plants, the chemical industries, the automobile traffic, the use of pesticides and fertilizers and the long-range atmospheric transport across the national boundaries.

The conventional way of studying atmospheric deposition of heavy metals and toxic elements is analysis of samples from bulk precipitation collectors. Routine precipitation sampling is limited to a small number of sites, the concentrations of most elements in precipitation are very low, and contamination problems associated with the sampling are often encountered.

Another method to measure the integrated heavy metal deposition is the use of terrestrial mosses growing on the ground in forests and other natural habitats. Moss technique used for atmospheric assessment was described first by Rühling [1]. Moss species are especially suitable for monitoring heavy metal pollution due to the high cation-exchange capacity of their cell walls. The main mechanisms of metal uptake are: ion exchange, intracellular uptake and particulate entrapment [2-5]. Mosses are utilized quite extensively in assessing atmospheric wet and dry deposition. Moreover they do not have a root system, and therefore the contribution from sources other than atmospheric deposition is in most cases limited.

This technique has been used regularly for the last 20 years in the Scandinavian countries for routine monitoring of atmospheric deposition of metals with a very high spatial resolution, and has more recently been adapted in an increasing number of European countries. The European Moss Survey began as a joint Danish and Swedish project in 1980 [6] and an extended survey in 1985 [7], in 1990-1991 were included Latvia, Estonia Lithuana, NW margin of Russia [8], in 1995-1996 new countries were Belarus and Ukraine [9].

What is the situation in Bulgaria?

Several investigations on the airborne pollution and impact studies using mosses as biomonitors have been done in Bulgaria [10-19]. Bulgaria was included in the project Atmospheric Heavy Metal Deposition in Europe using Mosses in 1995 [9,20].

In the framework of the International project REGATA [21], the heavy metal atmospheric deposition in the western and southern parts of Bulgaria (about 100 different sites) has been investigated in 2000 using the moss biomonitoring technique and instrumental nuclear activation analysis (INAA).

Experimental Procedure

Sampling

Certain moss species are abundant in large parts of the temperate zone (*Hylocomium splendens* and *Pleurozium schreberi*, for example), and their growth pattern is such that the annual increment can be readily identified. During the previous moss survey in Bulgaria 6 moss species were selected [20]. It turned out that the most abundant on the territory of Bulgaria was the moss *Hypnum cupressiforme*. This moss is widespread, said to be nearly cosmopolitan. It could be found in Bulgaria on marble and silicate rocks, on dead wood, soil and live stems of deciduous tree species, and showed great interspecies variability.

The sampling was carried out according to the guidelines described in detail in [22–24]. The sampling net was chosen as 10x10 sq. km and sampling sites (Fig.1) were located at least 300 m from the main roads and populated areas, and at least 100 m from smaller roads or single houses.

Fig.1. Sampling sites

Analysis

The whole alive part corresponding approximately to 3 years growth of *Hypnum cupressiform* was taken for analysis. Therefore the results from the survey 2000 represent the average deposition situation during the 1998-2000 for elements retained in the moss.

Moss samples of about 0.3 g in weight were packed in aluminum cups for long term irradiation or in polyethylene foil bags for short-term irradiation. The elements yielding of long-lived isotopes were determined using the Cd-screened channel 1 (Ch1) (epithermal neutron activation analysis, ENAA) at the pulsed reactor IBR-2 at the Frank Laboratory of Neutron Physics (FLNP), Dubna, Russia (Table 1) [21].

Table 1. The flux parameters of irradiation sites

Irradiation sites	Neutron flux density $(n/cm^2s)\cdot 10^{12}$		
	Thermal	Resonance	Fast
	E=0 – 0.55 eV	E=0.55 – 10^5 eV	E=10^5 – 25 10^6 eV
Ch1 (Cd-screened)	0.023	3.31	4.32
Ch2	1.23	2.96	4.10

Samples are irradiated for 5 days, re-packed and measured twice after 4-5 and 20 days of decay, respectively. The measuring time varied from 1 to 5 hours. To determine the short-lived isotopes (Na, Mg, Al, Cl, K, Ca, Mn, I, and Br (^{80}Br)) the 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.

Data processing and element concentration determinations were performed based on certified reference materials and flux comparators using software developed in FLNP, JINR [25].

Results and discussion

Analytical Quality Assurance

The quality assurance is an important part of any analytical study [26,27]. In our experiments the analytical quality assurance was evaluated by results of standard reference material Lichens-336 (IAEA, Vienna), as shown in Table 2.

Table 2. Results of the analysis of IAEA SRM Lichen-336. Concentration in ppm

Element	Na	Fe	Cr	Co	Pb	Cu	Zn	Fe	Cd
Recommend	320	426	1.03	0.287	5.0	3.55	31.6	426	0.117
Determined N=17	300± 30	400±20	1.10±0.09	0.33±0.04	4.5±0.3	3.1±0.2	26±2	420±10	0.12±0.02

Quality of the results is demonstrated also in Fig. 2. There is a good agreement between the concentration of antimony in the measured samples determined through isotopes of ^{122}Sb (554.3 keV) in the first measurement after radiation and ^{124}Sb (1691 keV) in the second measurement after radiation, as well as between crust elements Al (short-lived isotope) and Sc (long-lived isotope).

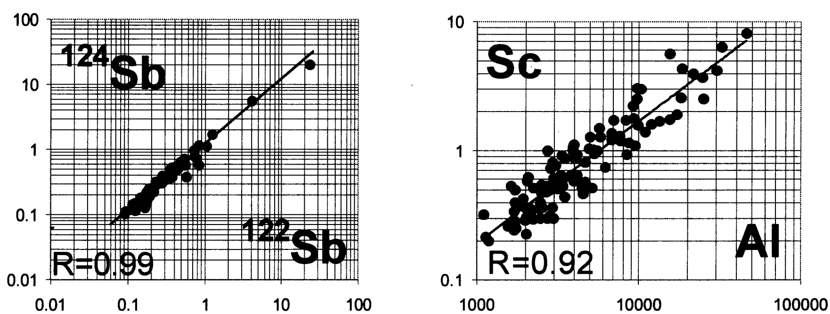

Fig. 2. Graphs demonstration quality control of the results

The mean values and ranges of the element concentrations for the studied regions of Bulgaria are shown in Table 3. They are compared with data for the other areas from Russia: the Urals [28] and Tula region [29], Poland (Copper Basin) [30], Norway (Mo and Rana, iron-chromium smelter) [31], and with the Norwegian background values [32-33].

Table 3. Element concentration in moss from Bulgaria and in some other relevant areas

	Bulgaria Western and South		**Russia** Ural [8]		**Russia** Tula [9]		**Poland** Coper basin [10]		**Norway** Mo [11]		**Norway**[12,13} background level
Moss species	*Hypnum cupressiform*		*Hylocomium splendens, Pleurozium schreberi*				*Pleurozium schreberi*		*Hylocomium splendens*		
	Mean	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
Element	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
Na	878	155 - 6918	394	174 - 1051	403	147 - 882	152	74 - 302	294	93 - 615	200
Mg	2575	748 - 12500	5003	1353 - 15400	2878	1160 - 4982	1694	800 - 6480	1861	556 - 4230	1200
Al	6534	1111 - 46350	2819	810 - 7000	2486	402 - 6015	815	237 - 2590	1244	243 - 3100	350
Cl	208	84 - 1180	314	44 - 1114	859	232 - 2521	226	113 - 537	294	50 - 1110	200
K	6304	3274 - 20490	6842	2642 - 13260	19628	8910 - 42230	5005	515 - 8708	3845	1930 - 7160	3000
Ca	7895	2266 - 19650	5093	2030 - 13800	7260	3290 - 12380	2229	1190 - 12800	2871	1450 - 6740	1500
Sc	1.17	0.20 - 8.05	0.6	0.10 - 1.45	0.39	0.09 - 1.19	0.15	0.03 - 0.63	0.41	0.06 - 1.41	0.06
V	13.2	2.2 - 112.6	8.5	2.0 - 22.4	11.2	1.38 -62	2.6	1.14 -8.13	5.72	1.05 - 31.0	2
Cr	5.05	0.5 - 26.9	18.6	2.2 - 194	2.95	0.88 - 9.6	1.43	0.80 - 3.16	11.7	0.5 - 50	1.5
Mn	272	32 - 986	344	88 - 1402	391	100 - 817	287	65 - 847	384	89 - 1460	200
Fe	3517	692 - 23110	1888	335 - 7438	3030	471 - 19670	520	219 - 1405	12280	700 - 72100	400
Co	1.74	0.23 - 12.65	0.64	0.14 - 1.95	0.13	0.05 - 0.29	0.32	0.11 - 1.96	0.61	0.06 - 2.2	0.3
Ni	5.43	0.5 - 18.6	8.4	0.96 - 94	0.53	0.21 - 1.21	2.49	0.21 - 38	1.69	<0.5 - 6.96	1.6
Zn	55.4	21.3 - 378.8	72	14.8 - 304	69	27.15 - 105	41	21 - 83	99	31 - 397	36
As	2.14	0.3 - 59	2.17	0.63 - 9.7	0.51	0.11 -1.47	0.73	0.12 - 6.04	0.62	0.06 - 2.20	0.3
Se	0.28	0.01 - 1.18	0.34	0.02 - 1.1	0.13	0.05 - 0.20	0.32	0.10 - 0.77	0.47	0.21 - 1.17	0.25
Br	4	1.1 - 11.6	6.2	1.52 - 25	4.05	1.44 - 12.7	1.38	0.89 - 2.85	6.94	3.6 - 12.2	5
Rb	15.6	3.5 - 69.1	10.3	02.08.39	19	6,2-32	21	1.95 - 45.51	17.2	6.7 - 46.2	10
Sr	28.93	7.1 - 99.3	18	1.96 - 65			12.4	0.69 -339			
Mo	1.18	0.2 - 3.4	0.29	0.041 - 0.71			0.29	0.05 - 2.42			
Ag			0.124	0.011 - 0.47	0.06	0.02 - 0.15	0.12	0.02 - 1.74	0.059	<0.03 - 0.16	0.04
Cd			0.63	0.16 - 2.86			0.3	0.03 - 1.07			
Sb	0.55	0.07 - 20.2	2.63	0.08 - 29	0.13	0.05 - 0.7	0.26	0.12 -0.79	0.25	<0.05 - 0.76	0.09
I	1.54	0.6 - 4.4	1.35	0.51 - 3.41	1.58	0.51 - 4.3	1.14	0.35 - 2.68	2.26	<1.0 - 4.3	2
Cs	0.55	0.10 - 2.44	0.22	0.04 - 0.61	0.2	0.06 - 0.48	0.43	0.08 - 1.29	0.37	<0.05 - 1.03	0.18
Ba	82	16.9 - 517	44	6.3 - 125	65	10 - 145	13.6	5.47 - 79	33.1	12.0 - 83.0	24
La	4.8	1.1 - 23.7	2.43	0.47 - 13	2.4	0.42 - 6.75	0.52	0.14 - 1.61	0.69	<0.10 - 2.87	0.3
Ce			3.24	0.53 - 11.7	3.45	0.64 - 10.9	1.27	0.24 - 3.74			-
Sm	0.62	0.07 - 2.86	0.29	0.07 - 1.05	0.4	0.08- 1.05	0.13	0.06 - 0.63	0.33	0.05 - 1.34	0.06
Tb	0.104	0.016 - 0.61	0.035	0.004 - 0.17	0.04	0.004 - 0.126	0.01	0.003 - 0.09	0.019	<0.005 - 0.07	0.015
Yb	0.23	0.03 - 1.87	0.107	0.005 - 0.55	0.13	0.028 - 0.138	0.04	0.01 - 0.18	0.069	<0.01 - 0.230	0.03
Hf	0.807	0.11 - 7.41	0.276	0.023 - 1.78	0.45	0.08 - 1.51	0.13	0.01 - 0.58	0.179	<0.04 - 0.71	0.05
Ta	0.115	0.018 - 0.563	0.045	0.004 - 0.48	0.04	0.01 - 0.13	0.02	0.004 - 0.13	0.043	<0.003- 0.18	0.005
W	0.272	0.03 - 0.826	0.34	0.06 - 1.27	0.14	0.05 - 0.40	0.17	0.02 - 0.62	1.71	<0.6 - 6.4	-
Au	0.0071	0.001 - 0.046	0.011	0.002 - 0.086	0.02	0.005 - 0.067	0.005	0.0004 - 0.02	0.0002	<0.0001-0.01	-
Th	0.923	0.11 - 4.53	0.36	0.054 - 1.72	0.47	0.095 - 1.46	0.13	0.05 - 0.45	0.267	0.04 - 1.10	0.08
U	0.349	0.05 - 1.87	0.15	0.057 - 0.73	0.18	0.052 - 0.59	0.1	0.02 - 0.99	0.143	<0.03 - 0.51	0.05

Table 4. Correlation coefficient matrix of moss from Bulgaria

	Na	*Mg*	*Al*	*Cl*	*K*	*Ca*	*Sc*	*V*	*Cr*	*Mn*	*Fe*	*Ni*	*Co*	*Zn*	*As*	*Se*	*Br*	*Rb*	*Sr*	*Mo*	*Sb*	*I*	*Cs*	*Ba*	*La*	*Sm*	*Tb*	*Yb*	*Hf*	*Ta*	*W*	*Au*	*Th*	*U*
Na	1,00																																	
Mg	**0,87**	1,00																																
Al	**0,88**	**0,97**	1,00																															
Cl	0,11	0,14	0,14	1,00																														
K	0,66	**0,72**	0,67	0,26	1,00																													
Ca	0,22	0,23	0,16	0,05	0,34	1,00																												
Sc	**0,83**	**0,92**	**0,92**	0,07	0,55	0,13	1,00																											
V	**0,88**	**0,87**	**0,88**	0,13	0,55	0,25	**0,89**	1,00																										
Cr	0,68	**0,84**	**0,84**	0,07	0,51	0,16	**0,87**	**0,70**	1,00																									
Mn	0,59	0,47	0,51	0,17	0,48	0,04	0,44	0,50	0,39	1,00																								
Fe	**0,82**	**0,92**	**0,93**	0,12	0,59	0,18	**0,96**	**0,89**	**0,90**	0,46	1,00																							
Ni	0,56	0,65	**0,71**	0,16	0,33	0,00	**0,74**	0,67	**0,76**	0,41	**0,77**	1,00																						
Co	**0,72**	**0,80**	**0,84**	0,26	0,39	0,04	**0,83**	0,85	**0,73**	0,45	**0,87**	**0,72**	1,00																					
Zn	0,03	0,04	0,06	0,00	0,15	0,34	0,07	0,10	0,07	0,00	0,12	0,17	-0,04	1,00																				
As	0,35	0,21	0,24	0,06	0,29	0,16	0,17	0,16	0,18	0,45	0,21	0,08	0,11	0,02	1,00																			
Se	0,04	-0,01	0,01	-0,04	0,15	0,13	0,03	0,08	-0,05	0,12	0,08	0,02	-0,02	0,39	0,18	1,00																		
Br	0,42	0,35	0,38	0,33	0,30	0,24	0,40	0,50	0,33	0,29	0,45	0,46	0,34	0,42	0,07	0,23	1,00																	
Rb	0,48	0,50	0,52	0,07	0,53	0,03	0,46	0,39	0,38	0,37	0,47	0,34	0,30	0,30	0,05	0,16	0,36	1,00																
Sr	0,54	0,57	0,57	0,04	0,47	0,24	0,56	0,57	0,45	0,28	0,61	0,41	0,45	0,43	0,06	0,14	0,50	0,64	1,00															
Mo	0,28	0,32	0,30	0,08	0,41	0,32	0,26	0,30	0,20	0,04	0,32	0,25	0,20	0,31	0,04	0,46	0,36	0,29	0,39	1,00														
Sb	0,04	0,08	0,09	0,01	0,13	0,46	0,08	0,15	0,05	0,07	0,11	0,10	0,02	0,51	0,10	0,47	0,34	0,19	0,21	0,39	1,00													
I	0,51	0,50	0,48	0,12	0,48	0,34	0,46	0,56	0,36	0,37	0,51	0,41	0,36	0,18	0,12	0,29	0,64	0,26	0,43	0,35	0,19	1,00												
Cs	0,54	0,63	**0,65**	-0,01	0,54	0,11	0,62	0,47	0,56	0,37	0,60	0,47	0,39	0,20	0,19	0,02	0,31	**0,71**	0,51	0,31	0,17	0,29	1,00											
Ba	0,60	**0,64**	0,65	-0,03	**0,70**	0,10	0,59	0,51	0,52	0,39	0,62	0,42	0,37	0,18	0,15	0,21	0,34	**0,72**	0,67	0,42	0,06	0,47	0,70	1,00										
La	**0,75**	0,76	**0,79**	0,09	0,59	0,10	**0,74**	**0,72**	0,63	0,41	**0,75**	0,58	0,60	0,14	0,13	0,06	0,52	0,57	0,59	0,45	0,13	0,43	**0,67**	**0,69**	1,00									
Sm	**0,75**	**0,81**	**0,85**	0,09	0,54	0,09	**0,84**	**0,74**	**0,74**	0,40	**0,83**	0,68	**0,70**	0,10	0,14	-0,01	0,42	0,53	0,59	0,40	0,12	0,41	**0,72**	0,68	0,85	1,00								
Tb	**0,81**	**0,83**	**0,89**	0,15	0,51	0,04	**0,86**	**0,80**	**0,75**	0,46	**0,86**	**0,73**	**0,79**	0,07	0,12	-0,02	0,46	0,55	0,59	0,30	0,07	0,43	0,67	0,66	0,85	**0,94**	1,00							
Yb	**0,71**	**0,74**	**0,81**	0,15	0,44	0,00	**0,79**	0,68	**0,74**	0,43	**0,78**	**0,71**	**0,70**	0,10	0,11	-0,02	0,45	0,54	0,51	0,26	0,12	0,36	0,69	0,61	0,83	**0,90**	**0,95**	1,00						
Hf	**0,84**	**0,82**	**0,85**	0,17	0,58	0,14	**0,84**	**0,83**	**0,71**	0,50	**0,86**	0,64	**0,77**	0,07	0,16	0,03	0,50	0,55	0,65	0,33	0,05	0,51	0,62	0,63	**0,79**	0,84	**0,89**	**0,83**	1,00					
Ta	**0,73**	**0,76**	**0,81**	0,11	0,55	0,03	**0,76**	0,66	0,68	0,43	**0,75**	0,60	0,64	0,12	0,13	0,11	0,42	0,64	0,56	0,44	0,15	0,39	**0,76**	**0,73**	**0,86**	**0,88**	**0,91**	**0,91**	**0,84**	1,00				
W	0,48	0,53	0,52	0,26	0,58	0,19	0,42	0,42	0,39	0,22	0,46	0,38	0,34	0,19	0,19	0,11	0,30	0,47	0,38	0,43	0,27	0,29	0,53	0,50	0,64	0,48	0,50	0,49	0,47	0,60	1,00			
Au	0,03	0,02	0,04	0,55	-0,07	-0,15	0,03	0,11	-0,05	0,06	0,05	0,12	0,21	-0,03	-0,02	-0,04	0,25	0,08	0,07	0,08	0,01	-0,03	-0,01	-0,05	0,07	0,06	0,13	0,13	0,08	0,11	0,01	1,00		
Th	0,69	**0,72**	**0,76**	0,05	0,59	0,16	0,69	0,65	0,57	0,42	0,71	0,54	0,54	0,25	0,13	0,13	0,49	0,70	0,66	0,48	0,27	0,39	**0,82**	**0,73**	**0,90**	**0,80**	**0,81**	**0,77**	**0,77**	**0,87**	0,67	0,04	1,00	
U	0,62	0,65	0,69	0,07	0,52	0,14	0,63	0,60	0,48	0,33	0,64	0,51	0,48	0,28	0,08	0,15	0,53	0,67	0,66	0,50	0,32	0,39	**0,77**	0,67	**0,87**	**0,78**	**0,78**	**0,74**	**0,70**	**0,82**	0,64	0,09	**0,96**	1,00

The correlation coefficient matrix (Table 4) shows the relationships between pairs of elements behavior during long range atmospheric transport. Graphs for some inter-element correlations (Fe-Cr; Yb-Tb, U-Th, etc.) are shown in Fig. 3.

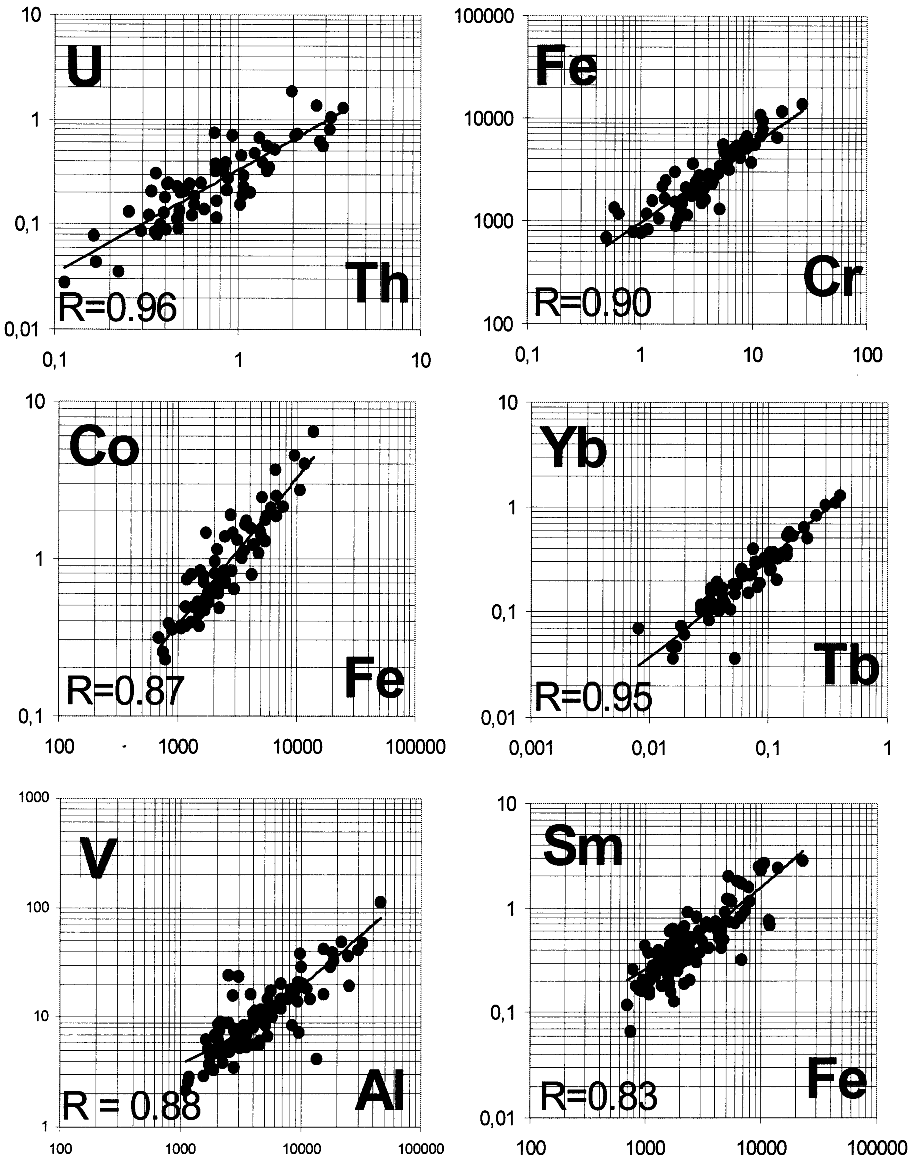

Fig.3. Graphs for some inter-element correlations

Applying the Principle Components Analysis (factor analysis) to the results obtained, it is possible to identify different sources such as crustal, marine, vegetation, industry, etc.), that contribute to the observed element concentrations, and to examine the roles they play with respect to individual elements. The results of factor analysis for the whole amount of data are given in Table 5. Tables 6 and 7 are based on data related to the south and western Bulgaria, respectively. Factors 1 and 2 represent mainly crustal (soil) material in every case. Factors 3 and 4 are apparently pollution-related. Factor 3 in Table 7 (As, Se) is likely to reflect coal burning. Factor 4 in Table 6 appears to be strongly affected by a zinc smelter in the south part.

A graphical technique developed for aerosols [34], for extracting the elemental compositions of the crustal, marine, and general pollution components and proved to be efficient for lichens [35] was successfully applied to Bulgarian 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 [36]. 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 10-100. These «enriched» elements are of noncrustal origin (Fig. 4).

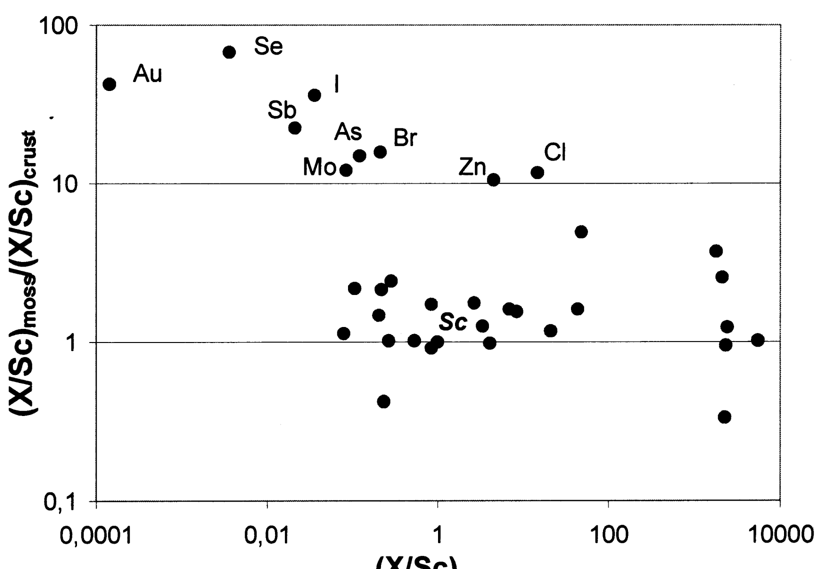

Fig. 4. Enrichment factors of elements in Bulgarian moss with respect to crust

The following elements are discussed with regard to the observed spatial trends as influenced by deposition of pollutants from the local point sources, long range atmospheric transport, etc.

Arsenic The elevated concentrations of this toxic and cancerogenic element are mainly related to the copper smelter; lead ores; coal-combustion in coal-fired power station without proper filters as well as to production of pesticides and herbicides. The very high As concentration observed around the town of Chiprovtzi (59 ppm) could be explained by cross-border pollution from Yugoslavia, the source of which is situated not far away from Chiprovtzi.

Chromium Cr is mainly associated with the crustal component. The main source of chromium pollution in the environment is local industry, especially iron and steel smelters. Combustion of coal may also lead to an increased chromium load on the ecosystem. A comparison of Cr concentration shows to be similar to the other investigated areas.

Iron The concentration of Fe in moss is explained by the soil factor, as indicated by the high Fe-Sc correlation (Table 4) and Principle Component Analysis (Table 5). However, a very high concentration of iron was observed around Burgas town (Drachevo village, 23110 ppm) to be likely due to local emission sources , namely ore mining and Third Metallurgical Plant.

Vanadium Vanadium as well as nickel is mainly emitted from coal and oil burning and from refineries. High values of vanadium were observed for Burgas region (for example, Drachevo village, 112.6 ppm). The reason for these high vanadium depositions can be associated with oil refinery in the town of Burgas and to a lesser extent by nearby metallurgical industries.

Nickel It is obvious that the element distribution pattern of vanadium corresponds to that of nickel. The main emission sources of nickel is oil and coal burning as well as locally steel industry and smelters. A slightly elevated Ni concentrations in mosses may be related to Burgas oil refinery.

Zinc Zinc is emitted by metal industry. High levels of Zn deposition are observed around the town of Kurdjali situated in the south part of Bulgaria and are undoubtedly related to previous and present atmospheric emission from lead and zinc smelters. Emissions from non-ferrous metal plant in the town of Kurdjali also contribute to zinc deposition patterns. Data of nine sampling sites near to this very polluted place show mean value about 160 ppm. Pollution with zinc may be caused by non-ferrous metal plant in the town of Plovdiv. Unfortunately there were only two sampling sites examined in the vicinity of this town: Bachkovo Monastery (154 ppm) and Biala reka village (96 ppm). Similar high values are typical for Zn and Pb smelters in Romania [37,38].

Tables 5,6,7. The results of factor analysis

Element	Bulgaria						
	Component						
	1	2	3	4	5	6	7
Na	**0.74**	0.36	-0.05	0.02	0.31	0.23	0.20
Mg	**0.82**	0.37	-0.06	0.00	0.14	0.13	0.28
Al	**0.85**	0.39	-0.03	0.01	0.17	0.10	0.17
Cl	0.07	0.01	-0.06	**0.88**	0.09	0.06	0.20
K	0.32	0.53	-0.04	0.05	0.34	0.27	**0.51**
Ca	0.09	-0.05	0.36	-0.08	0.01	0.14	**0.78**
Sc	**0.91**	0.28	0.02	-0.04	0.08	0.12	0.08
V	**0.85**	0.18	0.08	0.07	0.11	0.27	0.18
Cr	**0.86**	0.20	-0.01	-0.09	0.08	0.02	0.12
Mn	0.38	0.20	-0.01	0.10	**0.68**	0.27	-0.11
Fe	**0.90**	0.28	0.07	0.00	0.10	0.16	0.12
Ni	**0.80**	0.14	0.17	0.11	0.01	0.07	-0.13
Co	**0.90**	0.08	-0.03	0.20	0.07	0.07	0.01
Zn	-0.02	0.17	**0.74**	-0.04	-0.11	0.19	0.05
As	0.10	0.03	0.10	-0.01	**0.85**	-0.10	0.11
Se	-0.09	0.06	**0.70**	-0.07	0.31	0.19	-0.06
Br	0.34	0.20	0.45	0.36	-0.05	**0.51**	0.01
Rb	0.20	**0.79**	0.12	0.02	0.08	0.23	-0.10
Sr	0.38	**0.53**	0.24	-0.02	-0.11	0.45	0.06
Mo	0.14	0.40	0.50	0.11	-0.07	0.05	0.33
Sb	0.05	0.08	**0.83**	0.03	0.05	-0.15	0.22
I	0.37	0.12	0.22	0.05	0.12	**0.68**	0.25
Cs	0.41	**0.75**	0.09	-0.09	0.11	-0.04	0.01
Ba	0.34	**0.75**	0.03	-0.13	0.14	0.33	0.06
La	**0.63**	**0.65**	0.09	0.08	0.02	0.07	0.07
Sm	**0.77**	0.53	0.06	0.01	0.00	0.02	0.01
Tb	**0.82**	0.49	0.01	0.10	0.02	0.06	-0.06
Yb	**0.77**	0.51	0.06	0.11	0.02	-0.03	-0.13
Hf	**0.77**	0.44	-0.01	0.08	0.08	0.24	0.06
Ta	**0.65**	**0.68**	0.10	0.07	0.06	-0.01	-0.04
W	0.27	**0.62**	0.15	0.20	0.12	-0.18	0.38
Au	0.06	0.01	0.03	**0.83**	-0.05	0.00	-0.22
Th	0.52	**0.77**	0.20	0.03	0.04	0.04	0.07
U	0.47	**0.76**	0.28	0.08	-0.04	0.03	0.03
	Rotation converged in 8 iterations.						

Element	**South Bulgaria**			
.	Component			
	1	2	3	4
Na	**0.73**	0.62	-0.05	0.00
Mg	**0.76**	0.56	0.06	-0.01
Al	**0.79**	0.55	0.09	-0.01
Cl	-0.03	-0.21	0.41	**0.58**
K	**0.89**	0.14	0.19	-0.14
Ca	0.09	-0.08	**0.82**	0.16
Sc	0.42	**0.87**	-0.01	0.03
V	0.52	**0.72**	0.28	0.03
Cr	0.29	**0.92**	0.03	0.07
Mn	0.29	0.23	0.04	**0.54**
Fe	0.46	**0.86**	0.12	0.04
Ni	0.06	**0.81**	0.31	0.00
Co	0.25	**0.89**	0.08	0.12
Zn	0.03	0.01	**0.70**	0.07
As	0.25	0.34	**0.77**	0.10
Se	0.21	0.14	**0.80**	-0.02
Br	0.22	0.47	**0.65**	0.07
Rb	**0.77**	0.01	0.04	0.30
Sr	**0.71**	0.08	0.21	0.13
Mo	0.53	0.31	0.67	-0.07
Sb	0.05	0.06	**0.88**	0.18
I	0.40	0.41	0.32	-0.31
Cs	**0.84**	0.22	0.07	0.30
Ba	**0.90**	0.23	0.02	-0.07
La	**0.78**	0.31	0.17	-0.01
Sm	**0.70**	0.54	0.23	-0.11
Tb	**0.74**	0.63	0.13	-0.09
Yb	**0.72**	0.58	0.25	0.01
Hf	**0.80**	0.49	0.01	0.22
Ta	**0.86**	0.41	0.16	0.10
W	**0.70**	0.31	0.40	0.18
Au	0.14	0.07	0.17	**0.81**
Th	**0.83**	0.26	0.24	0.27
U	**0.80**	0.22	0.33	0.17
Rotation converged in 7 iterations.				

Element	Western Bulgaria						
	Component						
	1	2	3	4	5	6	7
Na	**0.58**	0.24	-0.16	0.22	**0.59**	-0.05	0.20
Mg	**0.89**	0.22	-0.06	0.19	0.17	0.18	-0.08
Al	**0.89**	0.28	0.00	0.08	0.23	0.15	0.00
Cl	0.08	-0.13	0.04	0.02	-0.04	**0.93**	0.10
K	0.45	0.14	0.11	0.12	0.43	**0.56**	-0.17
Ca	0.17	-0.19	-0.23	**0.72**	0.08	0.16	-0.25
Sc	**0.86**	0.44	0.08	0.07	0.09	-0.03	-0.06
V	**0.84**	0.32	-0.02	0.15	0.22	-0.12	0.04
Cr	**0.89**	0.21	0.12	0.19	0.04	0.13	-0.15
Mn	0.18	0.15	0.09	-0.08	**0.85**	-0.07	-0.12
Fe	**0.85**	0.38	0.19	0.17	0.07	0.12	-0.08
Ni	**0.82**	0.36	0.19	0.02	0.01	0.14	-0.14
Co	**0.89**	0.31	0.14	0.02	0.00	0.13	-0.03
Zn	0.31	0.30	**0.70**	0.18	-0.08	-0.07	-0.16
As	0.05	-0.01	0.11	0.13	**0.84**	0.14	0.10
Se	-0.20	-0.13	**0.77**	0.02	0.11	-0.04	0.42
Br	0.19	0.34	0.17	**0.72**	-0.07	-0.01	0.19
Rb	0.36	**0.64**	0.24	-0.16	0.06	0.15	0.09
Sr	0.30	**0.55**	0.06	0.43	-0.05	-0.13	-0.20
Mo	-0.09	**0.49**	0.43	0.38	-0.17	0.16	0.34
Sb	0.29	0.26	**0.68**	0.02	0.23	0.00	0.21
I	0.12	0.14	0.24	**0.72**	0.17	-0.05	-0.04
Cs	0.47	**0.73**	0.03	0.02	0.22	0.05	-0.14
Ba	0.35	0.41	**0.45**	0.25	0.24	-0.06	-0.29
La	**0.68**	**0.67**	0.13	0.14	0.09	0.00	0.03
Sm	**0.65**	**0.70**	0.04	0.13	0.10	-0.07	-0.04
Tb	**0.73**	**0.64**	0.05	0.11	0.09	-0.04	0.00
Yb	**0.73**	**0.64**	0.10	0.10	0.05	-0.03	-0.02
Hf	0.42	**0.75**	0.10	0.36	0.07	0.08	-0.09
Ta	0.48	**0.74**	0.20	0.13	0.06	0.06	0.12
W	0.10	0.29	-0.16	-0.01	0.06	**0.88**	0.06
Au	-0.09	-0.02	0.19	-0.08	0.02	0.10	**0.86**
Th	0.43	**0.80**	0.10	0.11	0.15	0.11	-0.09
U	0.40	**0.83**	0.06	0.01	0.04	0.08	0.09
	Rotation converged in 8 iterations.						

The concentrations of most of the other elements in Bulgarian mosses are comparable with those given in Table 3.

In order to determine the concentrations of such important element as Pb, Cd and Cu atomic absorbtion has to be applied.

The more detailed analysis of the deposition patterns of element-pollutants in Bulgaria will permit
- to determine the regional extent of pollution caused by specific metals and other trace elements, including the rare earth's;
- to identify specially affected areas and local sources of emissions;
- to reveal the character and the origin of pollution sources within the area under investigation, as well as those sources affecting this area through long range atmospheric transport;
- to develop maps of the distribution of heavy metals using GIS technology for the purposes of environmental protection.

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Новые результаты изучения воздушных загрязнений в Болгарии с помощью мхов биомониторов (сбор мхов 2000–2001 гг.)

Приводятся новые результаты изучения воздушных загрязнений тяжелыми металлами и другими токсичными элементами в Болгарии с помощью мхов биомониторов (по результатам сбора мхов 2000–2001). Образцы мха были собраны в 103 точках в Болгарии вдоль границ с Югославией, Македонией, Грецией и Турцией. Анализ образцов проводили методом эпитеплового нейтронного активационного анализа на реакторе ИБР-2 ЛНФ ОИЯИ. Был определен широкий круг элементов, включая тяжелые металлы и редкоземельные элементы (Na, Mg, Al, Cl, K, Ca, Sc, V, Cr, Mn, Fe, Co, Ni, Zn, As, Se, Br, Rb, Sr, Mo, Sb, I, Cs, Ba, La, Sm, Tb, Yb, Hf, Ta, W, Au, Th и U). Полученные результаты согласуются со средними европейскими оценками для большинства элементов. Метод главных компонентов (факторный анализ) использовался для определения тяжелых и легких элементов земной коры, элементов растительного и антропогенного происхождения.

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New Results from Air Pollution Studies in Bulgaria (Moss Survey 2000–2001)

New results of moss survey 2000 of systematic study of air pollution with heavy metals and other toxic elements in Bulgaria are reported. The moss samples collected at 103 sites in Bulgaria, along the borders with Yugoslavia, Macedonia, Greece and Turkey were analyzed by instrumental activation analysis using epithermal neutrons (ENAA) at the IBR-2 pulsed fast reactor for a wide set of elements including heavy metals and rare earth elements (Na, Mg, Al, Cl, K, Ca, Sc, V, Cr, Mn, Fe, Co, Ni, Zn, As, Se, Br, Rb, Sr, Mo, Sb, I, Cs, Ba, La, Sm, Tb, Yb, Hf, Ta, W, Au, Th, and U). The results obtained are consistent with the mean European values for most of elements. The principle component analysis is applied to distinguish heavy and light crust elements and vegetation ones from those of anthropogenic origin.

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

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