CORRELATION OF ATMOSPHERIC DEPOSITION AND DISEASES IN THE EUROREGION NEISSE

O. WAPPELHORST, I. KÜHN, J. OEHLMANN, S. KORHAMMER, B. MARKERT

International Graduate School Zittau Markt 23 02763 Zittau Germany
Tel. ++49 3583 7715 0, Fax ++49 3583 7715 34, E-Mail: wappelhorst@ihi-zittau.de

XA0102859

Abstract:

A biomonitoring system using the mosses Pleurozium schreberi and Polytrichum formosum as biomonitors has been used to determine the degree of pollution in the Euroregion Neisse (ERN). This region, located in Central Europe where the borders Germany, Poland and Czech Republic meet (see Figure 1), was one of the most highly polluted areas in Europe until the early 1990s. For clarity and ease of access the results have been presented visually using a Geographical Information System (GIS) (Markert et al., 1999; Wappelhorst, 1999; Wappelhorst et al., 1999).
The deposition of 37 elements in the Euroregion as found in the moss study is compared with the incidence of various diseases, using data from regional hospitals. Connections between diseases of the respiratory tract and Ce, Fe, Ga and Ge deposition as well as between cardiovascular diseases and Tl were determined. The results will be validated by further studies with an even greater amount of data.

1. INTRODUCTION

The use of epiphytic plants as passive biomonitors is an established method of determining atmospheric deposition. In Scandinavia, mosses have been used as biomonitors for determining pollution with heavy metals since the late 1960s (Rühling & Tyler, 1968). Numerous projects have since been carried out with mosses; the method has been developed systematically (Ellison et al., 1976; Maschke, 1981; Engelke, 1984; Steinnes, 1984; Ross, 1990) and also used in large-scale European studies (Rühling, 1994; Siewers & Herpin, 1998; Markert et al., 1999). Mainly the endohydric mosses *Pleurozium schreberi* and *Hylocomium splendens* have been used in these studies.

Due to the fact that mosses have no cuticle layer, heavy metals and other elements are taken up through the surface of the mosses. This makes it safe to assume that the element concentrations correlate closely with the actual deposition of these elements, providing that disruptive factors such as soil particles or leaching processes can be excluded.
Atmospheric pollution causes different diseases in humans, although definite proof as to which substance triggers or causes a disease is very difficult.

2. METHODS

An investigation into the effects of atmospheric pollution on individuals over large areas involves the collection of data throughout the region. Biomonitoring is an excellent means of doing this. Such an approach was used by Cislaghi & Nimis (1997) in a study in which they compared the mortality rate from various pulmonary diseases with a biodiversity index for lichens. High correlation coefficients were found between the index and the number of deaths from lung cancer. However, no direct conclusions were drawn in respect to levels of individual elements.

2.1. Biomonitoring

In the years 1995 and 1996 the atmospheric deposition of elements in the Euroregion Neisse (ERN), located in Central Europe at the border of Poland, the Czech Republic and

Germany, was determined in a biomonitoring project using mosses. The mosses *Pleurozium schreberi* and *Polytrichum formosum* were chosen as biomonitors because of their wide distribution in the area studied and because their ability to take up metals from the atmosphere makes them optimal biomonitors.
The present study was the first attempt to compare pollution with numerous elements – detected by using mosses as biomonitors – with the incidence of disease (Wappelhorst, 1999; Wappelhorst et al., 1999).

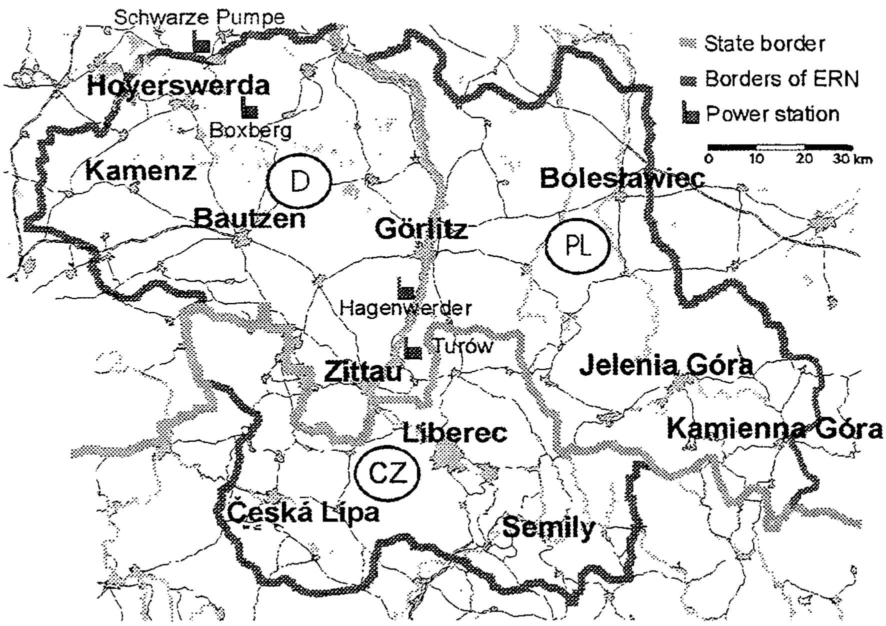

Figure 1: The Euroregion Neisse

The sampling sites were located at least 300 m from main roads or populated areas and at least 100 m from any road or single house. The moss samples were dried at 45°C without previous washing. A microwave-assisted digestion in closed PTFE vessels was done with 300 mg samples, 4 ml nitric acid and 2 ml hydrogen peroxide. The samples were analyzed by ICP-MS and ICP-OES for their concentrations of 37 chemical elements (Ag, Al, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Ge, K, La, Mg, Mn, Mo, Na, Nd, Nd, Ni, Pb, Pr, Rb, Sn, Sr, Ti, Tl, Th, U, V, Y, Zn and Zr). Using the Geographical Information System ARC/INFO the element contents were then interpolated (inverse distance method) and presented in map form. Standard reference material was used to check the quality of the analytical results (Markert, 1996).

In evaluating the general contamination, all elements analysed must be considered simultaneously. As the number of elements in question increases, the difficulty of this task increases as well, especially considering that the distribution curves can differ greatly from element to element.

For this reason we calculated a standardised contamination level which took all the element contents which had been determined into consideration. To accomplish this all element contents in the mosses were first standardised. Then the average standardised element content was calculated for each sampling point and interpolated exactly as for the individual element contents. Thus in areas where the standardised contamination level is higher than 0.3, the level of pollution, taking the average of all measured elements, lies more than 30% over the ERN average.

2.2. Health data

For every region investigated the average element content was calculated and then correlated with the health data.

The numbers of patients discharged from hospitals, including deaths, in the years 1993 to 1997 were taken as the basic data for the frequency with which a disease occurs. In Germany this data, which includes the diagnosis and the patient's sex, age and place of residence, is provided annually by hospitals to the Statistical Offices of the individual states. The diseases are classified according to ICD 9 (International Statistical Classification of Diseases and Related Health Problems, ninth revision, WHO) (Table 1).

Table 1: Classification of the diseases studied according to ICD 9.

ICD 9	Description of the Disease
140 - 208	**Neoplasms**
162	Malignant neoplasms of the trachea, bronchus and lung
172, 173	Malignant melanomas of the skin and other malignant neoplasms of the skin
204 - 208	Leukaemia
390 - 459	**Diseases of the circulatory system**
393 - 398, 410 - 429	Heart diseases
410	Acute myocardial infarction
411 - 414	Other forms of ischaemic heart disease
401 - 405	Essential and secondary hypertension
430 - 438	Diseases of the cerebrovascular system
460 - 519	**Diseases of the respiratory system**
480 - 486	Pneumonia
466, 490, 491	Bronchitis
490 - 496	**Chronic obstructive lung disease**
493	Asthma
680 - 709	**Diseases of the skin and subcutaneous tissue**
710 - 739	**Diseases of the musculoskeletal system and connective tissue**

Table 2: The European Standard Population according to Waterhouse (1976)

Age group	Number of people
0	1600
1 - <5	6400
5 - <10	7000
10 - <15	7000
15 - <20	7000
20 - <25	7000
25 - <30	7000
30 - <35	7000
35 - <40	7000
40 - <45	7000
45 - <50	7000
50 - <55	7000
55 - <60	6000
60 - <65	5000
65 - <70	4000
70 - <75	3000
75 - <80	2000
80 - <85	1000
85 +	1000
Total	100 000

We were able to evaluate the data from the districts of Bautzen, Kamenz, Löbau-Zittau, the Upper Lusatia district of Lower Silesia (NOL) and the county boroughs of Görlitz and Hoyerswerda. The data are classified according to sex and age (0 - <5, 5 - <10, ..., 80 - <85, 85 and over). The age structure, which has a bearing on the incidence of disease, differs from one area to another. In order to compare the disease figures for the individual areas it was nevertheless necessary to standardize them. Two possible methods of standardization were available.

In the first method the data were converted in accordance with the European Standard Population (see Table 2) (Waterhouse, 1976). The age groups are taken into account in the standardized overall incidence of a disease with a weighting that corresponds to their share of the standard population. In the second method the numbers of cases of the disease are converted to a figure per 100,000 inhabitants divided according to sex and age; the overall incidence of the disease per 100,000 inhabitants is then calculated. This method has the advantage that the data can be evaluated separately according to age and sex. But such a breakdown can lead to very small case numbers per group and thus cause major errors in the results. This does not happen with the first method. A further advantage of the first method is a great reduction of the individual data to be processed. Both methods were carried out.

To determine possible connections between deposition and disease, the incidence of the diseases was correlated with the element concentrations in the mosses. The concentrations of a number of elements in the mosses *Pleurozium schreberi* and, to a lesser extent, in *Polytrichum formosum* differ only slightly from one sampling site to another in the ERN. *A priori*, high correlation coefficients would result between these elements and all diseases that also show little geographic difference in incidence. But such correlations yield extremely little information; for this reason, only elements with a mean relative deviation of at least 35 % from the median were considered. In the ERN, differences of this magnitude were found for Ag, Al, Be, Bi, Ce, Cr, Cs, Fe, Ga, Ge, La, Li, Mn, Mo, Na, Nb, Nd, Pb, Pr, Rb, Sn, Th, Ti, Tl, U, V, Y and Zr in *Polytrichum formosum* and for Be, Bi, Cs, Mn, Na and Tl in *Pleurozium schreberi.*

The incidences of disease converted in accordance with the standard population (Method 1) and the numbers of cases broken down according to age and sex (Method 2) were correlated with the element concentrations in the moss samples from the various districts. The results are similar; for this reason, the results of Method 2 are only given in part here.

3. RESULTS

The element levels for Ce, Cr, Fe, Ge, La, Li, Nb, Nd, Ni, Pr, Th, Ti, U, V, Y and Zr in *Polytrichum formosum* around the Turów power plant and from the city of Liberec to the southern part of the ERN along the Neisse river valley are higher than the background values. These elements have highly significant correlation coefficients among themselves. A good example of this is the element distribution of Zr in *Polytrichum formosum* as well as the standardized contamination for *Polytrichum formosum*, shown in Figures 2 and 3, respectively. Dry deposition coming from sources south of the ERN are brought by atmospheric currents along the Neisse river valley. To the east the Iser Mountains and to the west the Zittau Mountains and the Lusatia Hills form natural barriers to a broader deposition pattern. Because of the topographical conditions in this part of the ERN, winds from the south and southwest are common, whereas in general westerly winds predominate.

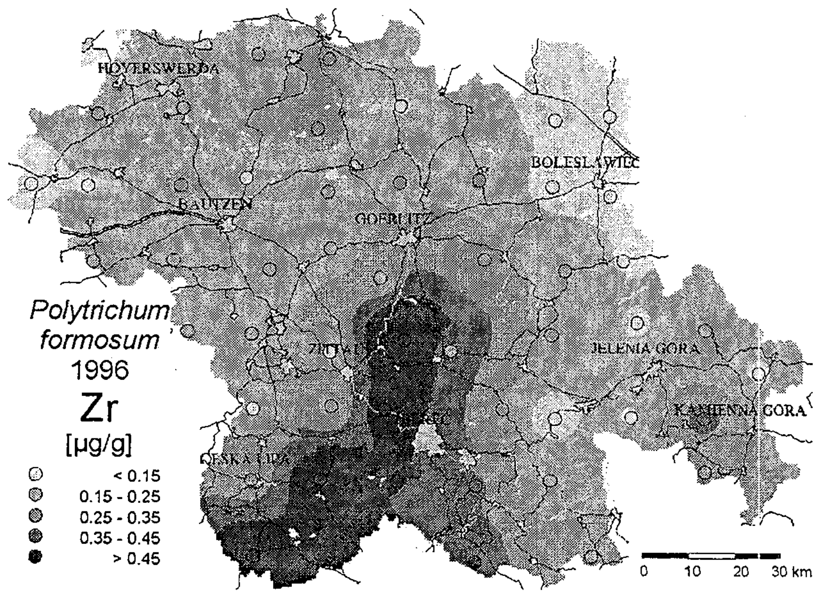

Figure 2: Zirkonium concentration in µg/g dry matter in Polytrichum formosum

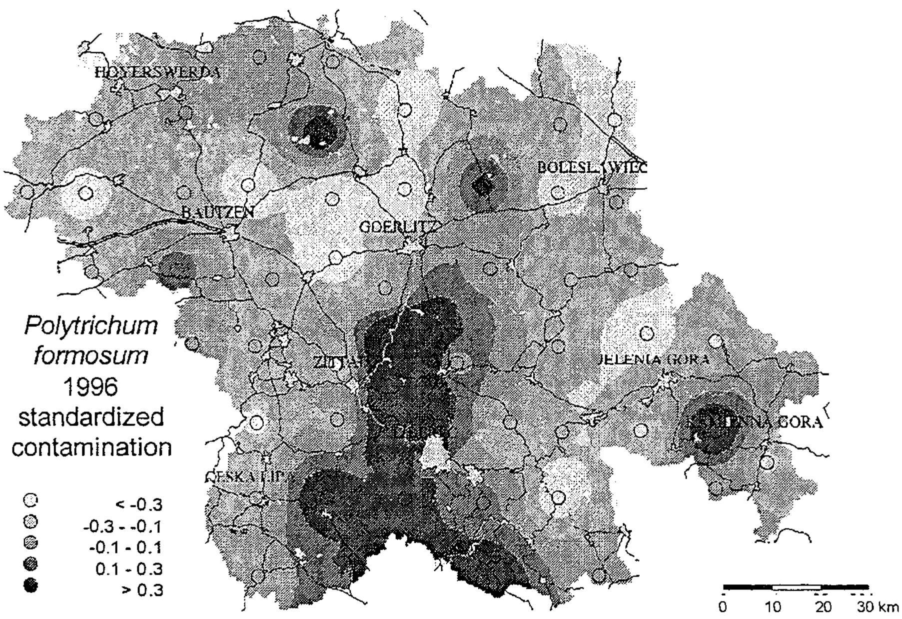

Figure 3: Standardized element concentration in µg/g dry matter in Polytrichum formosum

Significant correlations ($p \leq 0.1$) between the element concentrations in the mosses and the incidence of the diseases covered by the survey are shown in Table 3. For the sake of simplicity the remaining correlation coefficients are not included. The fact that a disease is caused or promoted by increased rates of deposition of an element would be reflected in a positive correlation; positive correlation coefficients are therefore printed in bold type. Negative correlations may be interpreted as a „protective effect“ of an element against the disease concerned.

The concentrations of the elements Ce, Fe, Ga and Ge in *Polytrichum formosum* correlate significantly with the incidence of malignant neoplasms of the trachea, bronchus and lung (ICD 162) and the incidence of diseases of the skin and subcutaneous tissue (ICD 680-709).

There is a significant positive correlation between the thallium (Tl) concentrations detected in the moss *Polytrichum formosum* and the incidence of diseases of the circulatory system in general (ICD 390-459); in particular there is a correlation with essential and secondary hypertension (ICD 401 - 405), acute myocardial infarction (ICD 410), other forms of ischaemic heart disease (ICD 411-414) and chronic obstructive lung disease (ICD 490-496). The Tl concentration in *Pleurozium schreberi* also correlates significantly with the incidence of essential and secondary hypertension (Table 3). The evaluation according to age groups (Method 2) gives a very clear indication of the connection between Tl concentrations and the occurrence of acute myocardial infarction and hypertension in the age groups over 40 (*Pleurozium schreberi*, Table 4) and over 25 years of age (*Polytrichum formosum*, Table 5). In the older age groups there are highly significant correlations for both men and women. Since Tl and K have a similar ionic radius (150 pm and 151 pm respectively), Tl has an effect on the conduction system of the heart and the cardiac muscle (Marquart & Schäfer, 1997).

Table 3: Correlations between the incidence of diseases and the mean element concentrations in the moss samples from each district. Only significant correlation coefficients ($p \leq 0.1$) are shown; positive correlation coefficients are printed in bold type. (D.: diseases)

A *Polytrichum formosum*

	Malignant neoplasms	... of trachea, bronchus and lung	... of skin	Leukaemia	**Diseases of the circulatory system**	Heart diseases	Essential and secondary hypertension.	Acute myocardial infarction	Other forms of ischaemic heart disease	Diseases of the cerebrovascular system	**Diseases of the respiratory system**	Pneumonia	Bronchitis	Chronic obstructive lung disease	Asthma	**Skin disease**	**D. of the musculo-skeletal system & connective tissue**
Al																	
Ag																	
Be																	
Bi											-0.81						
Ce		**0.73**														**0.74**	
Cr																	
Cs																	-0.90
Fe		**0.91**														**0.81**	
Ga	-0.73	**0.95**	**0.79**									**0.86**				**0.86**	
Ge		**0.74**					**0.81**									**0.77**	
La																	
Li	**0.78**		-0.91				-0.73					-0.90				-0.82	
Mn	**0.80**	-0.77				**0.77**				**0.76**							
Mo		-0.86	-0.80													-0.77	
Na											-0.82						
Nb	**0.76**																
Nd				**0.75**											-0.75		
Pb																	
Pr															-0.73		
Rb																	
Sn				**0.80**													
Th				**0.78**								-0.74					
Ti													**0.73**				**0.92**
Tl				-0.77	**0.78**		**0.83**	**0.92**	**0.84**					**0.86**			
U			-0.74														
V																	**0.85**
Y																	
Zr																	**0.87**

B *Pleurozium schreberi*

	Malignant neoplasms	... of trachea, bronchus and lung	... of skin	Leukaemia	**Diseases of the circulatory system**	Heart diseases	Essential and secondary hypertension.	Acute myocardial infarction	Other forms of ischaemic heart disease	Diseases of the cerebrovascular system	**Diseases of the respiratory system**	Pneumonia	Bronchitis	Chronic obstructive lung disease	Asthma	**Skin disease**	**D. of the musculo-skeletal system & connective tissue**
Be																	
Bi			**0.82**									**0.73**					
Cs	-0.74	**0.73**	**0.96**				**0.79**									**0.85**	
Mn	**0.94**		-0.78									-0.75					
Na	**0.80**									**0.79**			**0.74**				
Tl		**0.88**	**0.85**				**0.87**					**0.79**				**0.90**	

Table 4: Coefficients of correlation between element concentrations in *Pleurozium schreberi* and the incidence of essential and secondary hypertension (ICD 401-405) in the years 1993-1997, broken down according to age groups. Significant correlations are printed in bold type.

	20 - 25	25 - 30	30 - 35	35 - 40	40 - 45	45 - 50	50 - 55	55 - 60	60 - 65	65 - 70	70 - 75	75 - 80	80 - 85	> 85	
Be	-0.10	-0.22	-0.02	-0.18	-0.14	-0.08	-0.01	-0.18	-0.12	-0.03	-0.12	-0.05	-0.10	-0.05	**Be**
Bi	0.33	0.38	-0.13	-0.08	0.44	0.45	0.01	0.20	0.59	**0.76**	0.69	**0.81**	**0.82**	**0.86**	**Bi**
Cs	0.46	0.54	-0.10	0.13	0.61	0.60	0.11	0.42	**0.76**	**0.85**	**0.84**	**0.90**	**0.94**	**0.92**	**Cs**
Mn	0.14	-0.23	0.63	0.44	-0.07	-0.33	0.29	-0.09	-0.36	-0.57	-0.48	-0.60	-0.63	-0.71	**Mn**
Na	0.46	0.07	**0.75**	**0.78**	0.31	0.10	0.66	0.36	0.05	-0.25	-0.12	-0.31	-0.36	-0.49	**Na**
Tl	0.49	0.39	-0.08	0.20	0.63	0.71	0.19	0.44	**0.81**	**0.96**	**0.92**	**0.98**	**0.99**	**0.99**	**Tl**

Significant correlations were found between concentrations of the elements Nd, Sn and Th in *Polytrichum formosum* and the incidence of leukaemia (ICD 204 - 208). In contrast to this, the correlation coefficient for Tl is significantly negative for leukemia. Practically nothing is known about the toxicity of Nd. The toxicity of inorganic tin (Sn) compounds is generally considered to be low, but tin organyls are suspected of having a carcinogenic effect (Oehlmann & Markert, 1997). Thorium (Th) may have a carcinogenic effect because of its radioactivity.

Chromates are carcinogenic; they mainly cause tumours of the nose and lungs (Marquart & Schäfer, 1997; Oehlmann & Markert, 1997). The Cr concentrations detected in *Polytrichum formosum* show a positive but not significant correlation (r = 0.63) with the malignant neoplasms of the trachea, bronchus and lung (ICD 162).

Significant correlations were found between the concentrations of such elements as Ce, Fe, Ga and Ge in the biomonitors and diseases of the respiratory tract. Ce may be regarded as non-toxic, and Fe is essential to all organisms. Ga is slightly toxic and has a stimulant effect like that of Ce. Ge is also thought to be non-toxic, but some Ge compounds are poisonous. These elements are found in dust deposits. Their sources are the burning of fossil fuels and the drifting of dust on the ground. High Fe concentrations in the mosses indicate a generally high level of pollution with dust, which may result in respiratory tract disease.

Table 5: Coefficients of correlation between thallium concentrations in *Polytrichum formosum* and the incidence of diseases in the ERN. Significant coefficients are printed in bold type. For a listing of the diseases indicated by the classification according to ICD 9 see Table 1.

ICD 9	<1 - 5	5 - 10	10 - 15	15 - 20	20 - 25	25 - 30	30 - 35	35 - 40	40 - 45	45 - 50	50 - 55	55 - 60	60 - 65	65 - 70	70 - 75	75 - 80	80 - 85	> 85
140-208		-0.50	0.30	-0.29	-0.14	**-0.76**	0.20	0.42	-0.15	-0.20	-0.30	-0.07	0.32	0.05	-0.41	-0.36	0.73	0.71
162			-0.68	-0.20	-0.14	-0.68	**0.84**	-0.13	-0.36	0.56	**0.77**	0.12	0.59	0.09	0.22	0.58	-0.19	0.36
172, 173			0.37	0.26	0.67	0.10	0.25	**0.81**	0.30	-0.40	-0.11	-0.51	0.30	0.07	**0.83**	-0.01	0.46	**0.79**
204-208		-0.30	**-0.80**	-0.53	**0.75**	-0.26	-0.65	0.04	0.02	0.36	-0.13	-0.65	-0.33	-0.68	-0.65	-0.67	-0.34	0.52
390-459	-0.27	-0.24	0.22	0.67	0.64	**0.82**	0.42	0.46	0.71	0.72	0.14	0.65	**0.92**	0.66	**0.82**	**0.78**	**0.86**	0.72
393-398, 410-429	-0.37	**-0.73**	**-0.75**	-0.52	-0.45	0.59	0.48	0.55	0.66	0.57	-0.06	0.45	**0.89**	0.48	**0.81**	0.64	**0.74**	0.49
401-405					**0.90**	**0.79**	0.56	0.60	**0.90**	0.65	0.64	0.66	**0.83**	0.69	**0.75**	0.70	0.70	0.61
410					0.31	**0.85**	0.70	**0.91**	**0.77**	**0.88**	0.58	**0.81**	**0.82**	**0.91**	**0.87**	**0.90**	**0.92**	**0.88**
411-414		-0.68	0.73	-0.40	-0.64	**0.94**	0.69	**0.76**	**0.75**	0.37	-0.17	**0.76**	**0.74**	0.72	**0.94**	**0.93**	**0.87**	**0.80**
430-438	**0.88**	-0.68	-0.68	-0.23	-0.41	**0.74**	0.17	0.19	0.65	0.42	0.21	0.68	0.60	0.42	0.45	0.45	0.66	0.66
460-519	0.24	-0.53	0.55	0.12	-0.21	0.22	0.28	0.39	0.59	**0.78**	**0.88**	**0.90**	0.64	**0.84**	**0.86**	0.66	**0.76**	0.60
466,490,491	-0.05	-0.34	-0.42	0.25	-0.21	0.40	**0.85**	0.65	0.66	**0.81**	**0.86**	**0.75**	0.48	**0.87**	**0.74**	0.70	**0.73**	0.36
480-486	0.23	0.05	0.27	0.34	0.58	0.07	0.52	0.59	**0.75**	**0.78**	0.55	0.56	0.42	0.64	0.40	0.53	0.63	0.52
490-496	0.46	0.48	**0.87**	0.59	0.62	**0.80**	**0.73**	**0.74**	0.54	0.31	**0.76**	0.71	0.56	**0.85**	**0.75**	0.73	**0.93**	0.63
493	0.51	0.45	**0.84**	0.64	0.68	**0.91**	0.21	0.56	-0.58	-0.11	0.39	-0.03	-0.01	-0.22	-0.57	0.27	-0.36	-0.17
680-709	**0.74**	0.68	0.51	0.16	**0.78**	0.33	0.47	**0.78**	0.38	0.73	0.21	-0.09	0.60	0.72	0.51	0.39	**0.80**	0.59
710-739	0.67	0.41	0.59	0.33	0.46	0.24	0.55	0.21	0.10	0.31	0.08	-0.15	0.05	0.14	0.43	0.29	0.25	0.62

4. SUMMARY

This is the first study comparing the level of pollution with numerous elements, determined by moss monitoring, with the incidence of various types of disease. For most of the elements, the region studied was found to have a level of pollution similar to that of many other European regions and can thus be regarded as a model case.

Since humans take these elements in chiefly by inhalation, a connection between pollution and diseases of the respiratory tract was to be expected. A connection was indeed found between such diseases and levels of the elements Ce, Fe, Ga and Ge in the mosses. Unexpectedly, however, a correlation was also proved to exist between thallium concentrations and heart disease.

In the case of some other elements, such as Cr, there seems to be a connection with certain diseases but no significant correlation was observed. The reason may be that the element concentrations in the deposits are only one of many factors involved in pollution. Other factors such as indoor air contaminants or personal habits may overlay the effects of atmospheric deposition.

The significant correlations found between the element concentrations in the mosses *Pleurozium schreberi* and *Polytrichum formosum* and the incidence of a disease can only provide indications as to the possible causes of the disease. Causality is not taken into account when the correlation coefficients are calculated. This means that correlations can never prove that a connection exists. To do so will be the task of further studies, for which these results may offer initial hints.

REFERENCES

[1] Cislaghi, C., Nimis, P.L., 1997: Lichens, air pollution and lung cancer. Nature 387, pp. 463-464.

[2] Ellison, G., Newham, J., Pinchin, M.J., Thompson, I., 1976: Heavy metal content of moss in the region of Consett (North-East England). Environ. Poll. 11, pp. 167-174.

[3] Engelke, R., 1984: Schwermetallgehalte in Laubmoosen des Hamburger Stadtgebietes und Untersuchungen zur Sensibilität bei experimenteller Belastung, Dissertation, Universität Hamburg.

[4] Markert, B., Wappelhorst, O., 1999: Biomonitoring of heavy metals and trace elements in the Euroregion Neisse. Ed.: International Atomic Energy Agency, Co-ordinated research project on validation and application of plants as biomonitors of trace element atmospheric pollution, analysed by nuclear and related techniques, Report on the First Research Co-ordinated Meeting (RCM), Vienna, Austria, Sept. 28th - Oct. 1st, 1998, pp. 66-73.

[5] Markert, B., 1996: Instrumental element and multi-element analysis of plant samples - methods and applications. J. Wiley & Sons, Chincester, 296p.

[6] Maschke, J., 1981: Moose als Bioindikatoren von Schwermetallimmissionen. In: Cramer, J. (Hrsg.): Bryophytum Bibliotheka 22, Vaduz.

[7] Marquart, H., Schäfer, S.G. (Hrsg.), 1997: Lehrbuch der Toxikologie, Spektrum Akademischer Verlag. Heidelberg.

[8] Oehlmann, J., Markert, B., 1997: Humantoxikologie. Eine Einführung für Apotheker, Ärzte, Natur- und Ingenieurswissenschaftler, Wissenschaftliche Verlagsbuchhandlung mbH, Stuttgart, 261p.

[9] Ross H.B., 1990: On the use of mosses (*Hylocomium splendens* and *Pleurozium schreberi*) for estimating atmospheric trace metal deposition. Water, Air Soil Poll. 50, pp. 63-76.

[10] Rühling, Å., Tyler, G., 1968: An ecological approach to the lead problem. Bot. Notisier 121, pp. 321-342.

[11] Rühling, Å., 1994: Atmospheric heavy metal deposition in Europe - estimations based on moss analysis, Nord 1994, 9, 53p.

[12] Siewers, U., Herpin, U., 1998: Schwermetalleinträge in Deutschland - Moos-Monitoring 1995/96. Hrsg.: Bundesanstalt für Geowissenschaften und Rohstoffe. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart. 199p.

[13] Steinnes, E., 1984: Monitoring of trace element distribution by means of mosses. Fresenius J. Anal. Chem. 317, pp. 87-97.

[14] Waterhouse, J. (Hrsg.), 1976: Cancer incidence in five continents. Vol. 3. IARC, Lyon.

[15] Wappelhorst, O., Kühn, I., Oehlmann, J., Markert, B., 2000, Deposition and Disease - A moss monitoring project as an approach to ascertaining potential connections. Science of the Total Environment, In prep.

[16] Wappelhorst, O., 1999: Charakterisierung atmosphärischer Depositionen in der Euroregion Neiße durch ein terrestrisches Biomonitoring. Dissertation, Internationales Hochschulinstitut Zittau, 189p.

[17] Wappelhorst, O., Winter, S., Heim, M., Korhammer, S., Markert, B., 1999: Terrestrisches Biomonitoring in der Euroregion Neiße – Grenzen und Möglichkeiten. In: Oehlmann, J., Markert, B.: Ökosystemare Ansätze und Methoden. Ecomed-Verlag. München. pp. 208-224.