

## The use of *Sphagnum recurvum* Pal. Beauv. as biological tests for determination of the level of pollution with fluorine compounds and sulphur dioxide in the environment

MARIA SWIEBODA, ANDRZEJ KALEMBA

Department of Protection of Nature and Natural Resources,  
Polish Academy of Sciences,  
Lubicz 46, 31-512 Kraków, Poland

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### Abstract

The green parts of the peat moss *Sphagnum recurvum* Pal. Beauv. were used as a biological test to evaluate the pollution level of the natural environment in the region of the aluminium works "Skawina" (Southern Poland) with fluorine compounds and sulphur dioxide. The moss samples were placed in nylon nets and exposed to the polluted air for 6 weeks, then the fluorine and sulphur content in them was determined. The results demonstrated the usefulness of this method for the purpose of establishing the range of influence of the emitted industrial pollution.

### INTRODUCTION

Mosses like lichens are highly susceptible to noxious substances present in industrial polluting emissions, therefore they are used more and more frequently as bioindicators of the degree of atmospheric air pollution (LeBlanc and Rao 1966, Ranft and Dässler 1972, Huckabee 1973, Maschke 1973, Düll 1974, Frahm 1976, Sarosiek et al. 1977, Grodzińska 1978). The particular moss species differ, however, in their reaction to toxic substances contained in the industrial emissions. In results from the experimental studies of Börtitz and Ranft (1972) that the species *Sphagnum Dill* (Ehrh.) is very sensitive to fluorine and sulphur dioxide. Therefore for biological tests the moss *Sphagnum recurvum* was used in studies on the influence of the emission of the aluminium works and electric power plant "Skawina" on the natural environment (Vistula valley).

The aim in view was to test the usefulness of detached green parts of this moss as a bioindicator of pollution of the given territory with fluorine and sulphur dioxide.

#### MATERIAL AND METHODS

The moss *Sphagnum recurvum* Pal. Beauv. was collected in a pine forest about 50 km distant to the south of the aluminium works and electric power plant "Skawina".

Samples of 100 g fresh mass were prepared from the green parts of the moss and placed in nylon nets with mesh size about 1 cm (Fig. 1) and hung up at a height of 3 m above ground at 20 points (Fig. 2).



Fig. 1. Sample "pack" of peat moss *Sphagnum recurvum* Pal. (Beauv.) prepared for exposure (Photo by J. Kurzyński)

After six weeks the total fluorine content in the samples was determined by the colorimetric method of Belcher with alizarine complexone and lanthanum nitrate at wavelength 620  $\mu\text{m}$ . Total sulphur was determined by the method of Nowosielski (1974).

As criterion for establishing the zones with different pollution levels was assumed an increase in the F and S contents in the exposed moss samples, in the bark substrate of *Parmelia* (*Hypogymnia*) *physodes* and in pine dead bark by 1-50, 50-150, 150-250, 250-500 and F above 500 per cent as compared with the control samples. When the moss samples

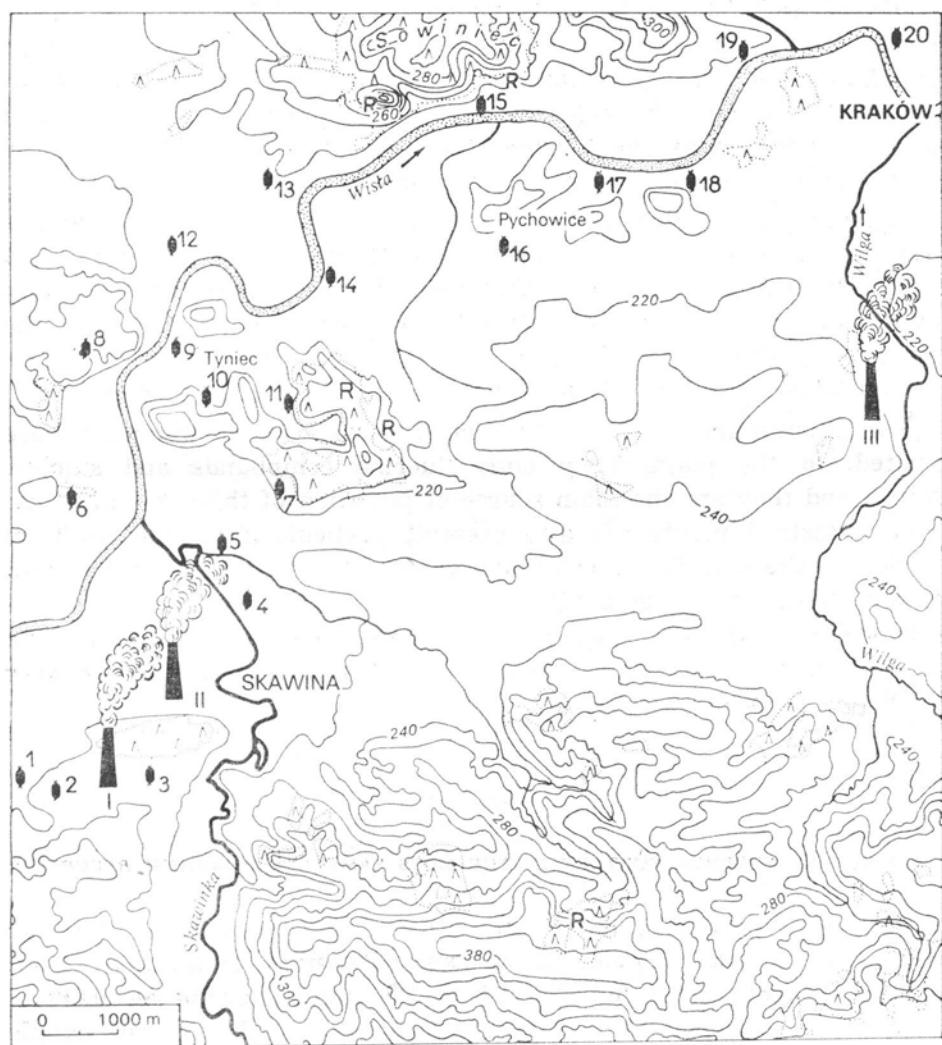


Fig. 2. Distribution of exposure sites for *Sphagnum recurvum* Pal. (Beauv.) on the area under study

I — aluminium works "Skawina"; II — electric power plant "Skawina"; III — Cracow Soda Plant; 1-20 — sites of sample exposure, R — nature reserves

were placed at the same sites where the lichen thallus was exposed and the dead pine bark collected, the maximal value in one of the mentioned bioindicators was taken as expressing the percentual increase in F and S for evaluating the pollution extent of the territory.

#### CHARACTERISTIC OF THE AREA INVESTIGATED

Studies on the influence of emission from the aluminium works and electric power plant "Skawina" were performed on an area of

about 150 km<sup>2</sup>. This area in its major part is a plain on the Vistula terrace comprising the river Wilga valley (Fig. 2). There stand out on this plain single Jurassic calcareous hills Wzgórza Tynieckie and Pychowickie and Krzemionki Zakrzowskie. On the north side the Vistula valley is bordered by the Wzgórze Sowiniec and on the South side by the Pogórze Wielickie eminences reaching 380 m a.s.l.

A large part of this area is occupied by the cities of Cracow and Skawina and covered by compact city settlement, the remaining part is of agricultural settlement character. Forests occupy a relatively small area and are mainly distributed on the Wzgórze Sowiniec the Wzgórza Tynieckie and the Pogórze Wielickie. The remaining larger tree agglomerations are of the character of settlement greenery.

The aluminium works and electric power plant "Skawina" are situated on the plain. They emit fluorine compounds and sulphur dioxide and they are the main source of pollution of this area, although other industrial plants are also present, particularly in the southern district of Cracow. The prevailing western winds and rather frequent eastern ones with a large contribution of foehn-like wind (halny) spread these gases in the air along the main axes of wind directions, while the terrain relief favours concentration of pollution in the air over the Vistula and Wilga valleys.

## RESULTS

### FLUORINE AND SULPHUR CONTENT IN THE MOSS SAMPLES (*SPHAGNUM RECURVUM*)

Total fluorine content in the green parts of the peat moss from the natural habitat was 23 ppm. In the exposed samples of moss, however, fluorine content varied between 28 to 106 ppm, showing an increase of 22 to 361 per cent (Table 1) as compared with the control sample not exposed to the emission of the aluminium works and electric power plant "Skawina". A particularly high fluorine content was found in moss samples placed on sites 1, 3, 4 and 5 closest to the aluminium works and further on sites 9, 10, 15, 16 and 20 in the Vistula valley.

The amount of sulphur in the material analysed was within the limits of 900 to 2500 ppm and with one exception was higher by 22 to 178 per cent than the natural S content in the green parts of peat moss (Table 1). In some cases (sites 5, 9, 10 and 11) the increased sulphur content in the moss corresponded to a high amount of fluorine, in others the values of these two elements were independent of one another. Hence no significant correlation was demonstrated between the amounts of sulphur and fluorine, similarly as in earlier investigations (Świeboda and Kalemba 1978a, 1979).

Table 1

Fluorine and sulphur content in moss (*Sphagnum recurvum* Pal. Beauv.) samples exposed to the contamination emitted by the aluminium works and electric power plant „Skawina”

Sampling site	Content ppm		Increase in reference to control sample, %	
	F	S	F	S
1	94	1100	308	22
2	48	900	109	—
3	87	1100	278	22
4	90	1400	291	56
5	106	2250	361	150
6	47	1600	104	78
7	34	1400	48	56
8	51	1600	122	78
9	70	2350	204	161
10	82	2500	256	178
11	53	2250	130	150
12	50	1300	117	44
13	40	1200	74	33
14	49	1100	113	22
15	91	1500	296	67
16	80	1200	248	33
17	28	1250	22	39
18	43	1550	87	72
19	29	1800	26	100
20	92	1650	300	83
21 control	23	900	100	100

#### EVALUATION OF THE POLLUTION LEVEL OF THE STUDIED AREA WITH FLUORINE COMPOUNDS BY MEANS OF BIOINDICATORS

The extent of pollution with fluorine and sulphur dioxide is presented on the basis of results obtained by means of three bio-indicators: the bark substrate of the lichen *Parmelia* (*Hypogymnia*) *physodes*; the dead bark of the pine *Pinus sylvestris* and the green parts of the peat moss (*Sphagnum recurvum*).

Pollution with fluorine compounds is heaviest within a radius of 1.5 km from the aluminium works (Fig. 3), owing largely to the fumes from the production house. The fluorine content in the bark substrate with lichen thallus and in the pine dead bark exceeded here by more than 500 per cent the control values.

The next zone in which fluorine content in the analysed material was 3-4 times higher than in the control extends along the Vistula valley and reaches to the southern slopes of the Wzgórza Tynieckie. The same pollution level of fluorine is found on a relatively small area

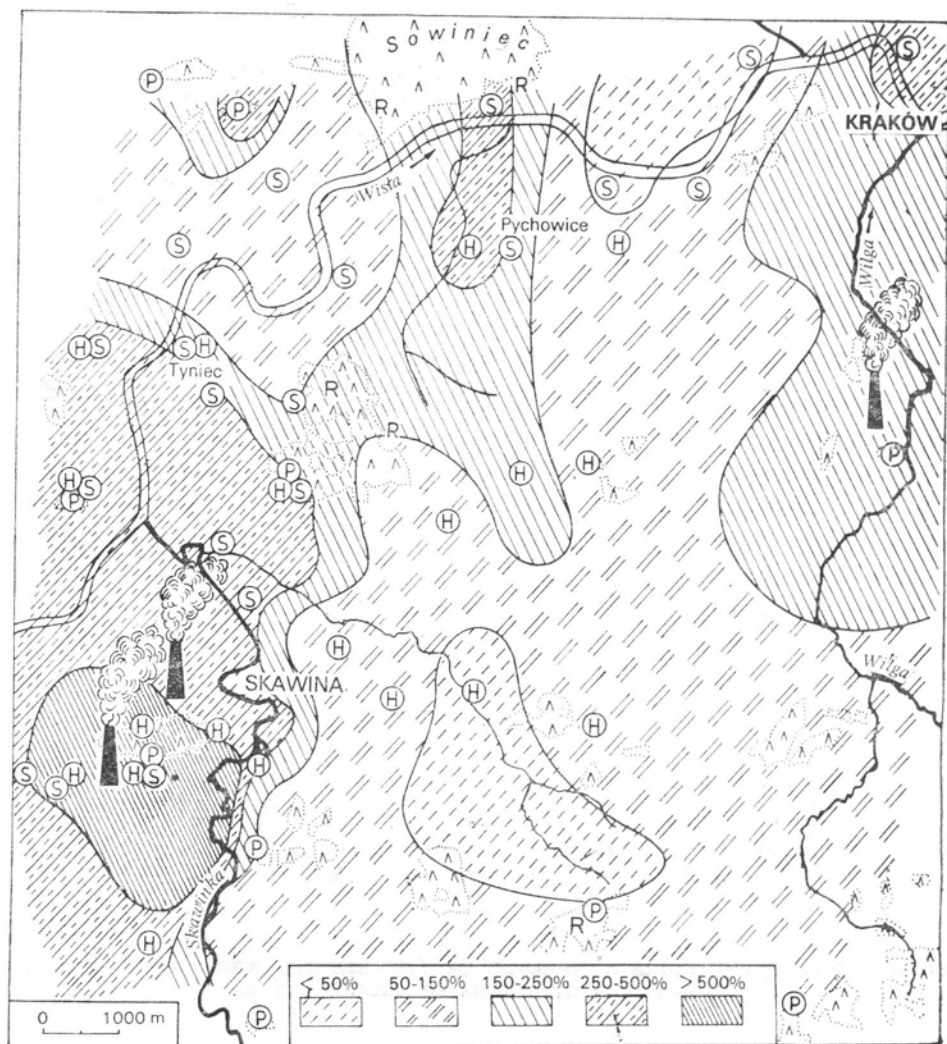


Fig. 3. Zones polluted with fluorine compounds

S — sites of *Sphagnum recurvum* Pal. (Beauv.) exposure; H — sites on which the lichen *Parmelia (Hypogymnia) physodes* (L.) Ach. was exposed; P — sites with *Pinus sylvestris* L. from which dead bark was collected

at the foot of the Wzgórze Sowiniec, Wzgórze Pychowickie and Wawel Hill. The intermediate zone characterised by an increase in fluorine content in the test samples by 150-250 per cent as compared to the control compares mainly the Wzgórza Tynieckie with the natural reserves "Skołczanka" and "Podgórk" and extends further along the Vistula valley to the reserves "Bieleńskie Skalki" and "Skalki Przegorzelskie". It also extends along the river Wilga reaching the centre of Cracow. Emissions from other industrial plants contribute no doubt to the increased fluorine concentration in this part of the area.

On a large part of the territory, particularly on the southeastern and north-western side, pollution with fluorine compounds is much less severe, the bioindicators showed an increase of F by 50-150 per cent as compared with the control.

Least polluted were two enclaves. One comprising a small torrent valley protected from the east and west by the Pogórze Wielickie, and the second on the northern side of the Wzgórze Pychowickie.

Pollution with sulphur dioxide is most severe between the aluminium works and the electric power plant "Skawina" and in the Vistula valley. As seen in Fig. 4, "stagnant" zones with a high SO<sub>2</sub> concentration in the air form at the foot of the Wzgórze Tynieckie on the southern

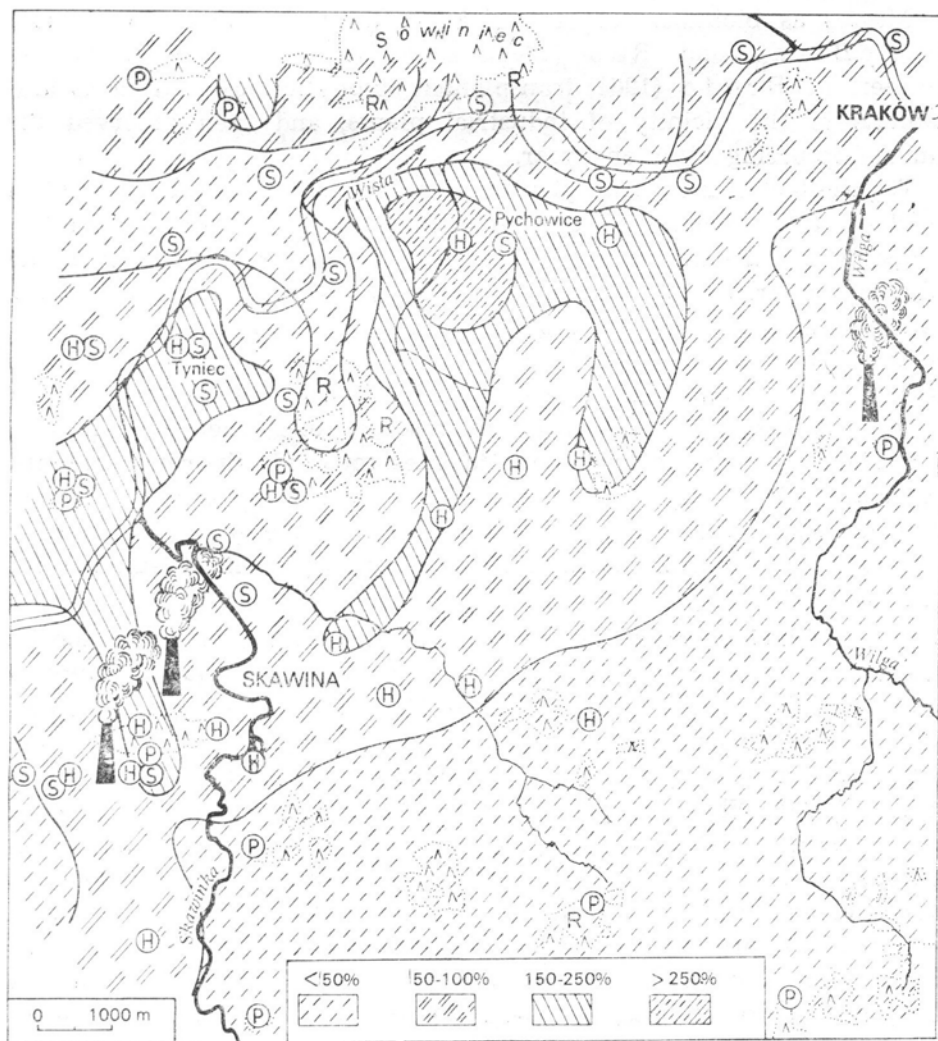


Fig. 4. Zones polluted with sulphur compounds (for S, H, P see Fig. 3)

side and close to the Wzgórza Pychowickie. Sulphur content in the test samples is here by 150-250 per cent higher than in the control samples, and in the region of Wzgórza Pychowickie it exceeds these values. On the remaining area pollution with sulphur dioxide is much less dangerous with an increase in the analysed material by 50-150 per cent and on the south-eastern and north-western part by as little as 50 per cent as compared with the reference value. All the above mentioned nature reserves lie in the latter two zones.

#### DISCUSSION

Mosses as bioindicators of the degree of air pollution were used by LeBlanc and Rao (1966). These authors basing on the experiment of Brodo (1961) transplanted epiphytic mosses from natural habitats to the vicinity of industrial plants, and then observed the damage occurring after one year.

The method of moss transplantation, according to Barkman (1968) could serve for diagnostic purposes if it could at the same time allow to distinguish the influence of the changed ecological conditions in the industrial district from damage caused by toxic substances. Mosses, namely, like lichens are susceptible both to drought and air pollution. In later investigations (LeBlanc et al. 1971) the influence of fluorine compounds on transplanted mosses was demonstrated on the basis of external injury and results of microscopic and chemical analysis, particularly of the chlorophyll, magnesium and fluorine contents. Frahm (1976) applying the method of moss transplantation, took into account, beside the ecological requirements of the particular species, the season, considering autumn or early spring as most suitable for these studies.

The method of chemical analysis of the particular moss species collected from their natural habitats is much more frequently applied in bioindicator studies (Tyler 1971, 1972, Rühling and Tyler 1973, Pakarinen and Tolonen 1976, Wallin 1976, Glooschenko and Capobianco 1978, Grodzińska 1978, Pakarinen 1978). When the polluting substances from industrial emission are found in the analysed samples in amounts exceeding their natural content in the given moss species, the results obtained are assumed as indices of the range of influence of the polluted air. Distribution of mosses on the territory is, however, dependent on the habitat conditions, this making impossible sample collection according to an established network of control points, indispensable for tracing the pollution zones.

To avoid this obstacle it was endeavoured in the present investigations to use detached green parts of the peat moss as a bioindicator

of the degree of pollution with fluorine and sulphur dioxide of the studied area. Moss samples in the form of "packs" could be exposed at the required points to the direct influence of polluted air for an adequately long time period.

In the exposed moss samples distinct differences were noted in fluorine and sulphur content in dependence on the situation of the site of exposure in relation to the sources of pollution. On sites with high fluorine compounds and sulphur dioxide concentration in the air the outer layer of the "pack" after 6 weeks became white, whereas on sites with a lower concentration of these gases the moss was only slightly discoloured and the sampled remained fresh to the end of exposure.

Death of the outer moss layer in the exposed "packs" inhibited no doubt or somewhat reduced the intensity of the physiological processes. This could, however, but slightly reduce the fluorine and sulphur content in the given sample since accumulation of both these elements occurred also mechanically. Evidence of this was obtained from the results of methods of lichen thallus transplantation (Świeboda and Kalemba 1978a, 1978b). Close to the aluminium works in spite of complete destruction of the lichen thallus, fluorine content in the bark substrate was highest and reflected the concentration of this gas in air.

The results obtained by exposure of the green parts of the moss *Sphagnum recurvum* proved to be in close agreement with those supplied by the method of transplantation of *Parmelia* (*Hypogymnia*) *physodes* thallus. Although both these tests may serve for bioindicator studies, exposure of the green parts of peat moss may find wider application since it is not associated with any technical difficulties.

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*Zastosowanie Sphagnum recurvum* Pal. Beauv. jako testu biologicznego do określenia poziomu skażenia środowiska związkami fluoru i dwutlenkiem siarki

Streszczenie

Zielone części mchu torfowca (*Sphagnum recurvum* Pal. Beauv.) zastosowano jako biologiczny wskaźnik do oceny poziomu skażenia badanego terenu związkami fluoru i dwutlenkiem siarki. Próby mchu, pochodzące z nie zanieczyszczono-

nego terenu, eksponowano w postaci "pakietów" (rys. 1) przez okres 6 tygodni w 20 ustalonych miejscach (rys. 2). Analiza chemiczna prób mchu, przeprowadzona po okresie ekspozycji, wykazała zróżnicowanie zawartości fluoru i siarki (tab. 1) w zależności od położenia danego stanowiska w stosunku do źródeł emisji związków fluoru i dwutlenku siarki. Na podstawie uzyskanych wyników oraz wcześniejszych danych (Świeboda and Kalemba 1978a, 1978b, 1979) wykreślono strefy zagrożenia badanego terenu przez związki fluoru (rys. 3) i dwutlenek siarki (rys. 4).