CONTEMPORARY HABITAT AND FLORISTIC CHANGES IN THE SUDETEN MTS.

JERZY FABISZEWSKI, TERESA BREJ

Department of Botany and Plant Physiology, Agricultural University
Cybulskiego 32, 50-205 Wrocław, Poland

(Received: January 14, 2000. Accepted: June 5, 2000)

ABSTRACT

The authors present the view that in the Sudeten for forty years parallelly eutrophication and acidification processes are taking place, as a result of industrial emissions. This view is based on results of bioindication studies on pollution and accumulation of sulphur, nitrogen and heavy metals. At the same time, after 30 years, vegetation and floristic changes were investigated on permanent plots on the Śnieżnik and in the Karkonosze Mts. In most habitats a decrease of pH over 1.0 has been recorded, even in areas with calcium bedrock. Acid rains containing a lot of nitrates contribute to the fertilization of most of the ecosystems. The yearly fall of total nitrogen in the Sudeten ranges from 38 kg in the Karkonosze, to 59 kg/ha on the Śnieżnik, of nitrates – from 380 to 900 ppm/year, and sulphur, on the average, 1300 ppm/year in the whole Sudeten. The acidification of soil causes the inaccessibility of alkaline elements (magnesium, calcium) and mobilization of harmful for plants aluminium. Overfertilization of habitats, the lack of calcium and magnesium and the excess of aluminium cause unfavourable alterations in all phytocenoses in the Sudeten. The high mountain forests are particularly suffering, but also the high mountain vegetation and above all the subalpine swards exposed to acid rains. Examples of plant species which adapt themselves to the new ecological conditions, and mountain plants which reduce their range are given. In general, the typical mountain flora and vegetation of the Sudeten is endangered in the existing ecological conditions.

KEY WORDS: eutrophication, acidification, Sudeten Mts, air pollution, decline of biodiversity.

INTRODUCTION

The region of the Sudeten is among the most afflicted areas by man's activity in Poland. Its effects concern not only the forest vegetation, where in the years 1970-1980 an ecological disaster took place, but they also affect the whole flora and vegetation cover of this region. The industrial pollutions which for decades reach the Sudeten come mainly, from brown coal combustion, caused changes in most of the habitats. These are not able to return fast to their natural condition, in spite of the distinctly lower, for several years, dust and gaseous emissions. Our paper presents the range of changes in soil conditions in the Sudeten, particularly in the areas of the Śnieżnik massif and in the Karkonosze, on the background of which the directions of floristic and vegetation changes in the discussed region are described. The alteration processes of the Sudeten vegetation cover in the Karkonosze and Śnieżnik massif, presented in previous papers (Fabiszewski, Brej 1992; Wojtuń et al. 1994; Brej, Fabiszewski 1996, 1997; Fabiszewski, Brej 1996), were connected with two parallelly proceeding and often overlapping phenomena, i.e., eutrophication and acidification. Similar changes taking place in other parts of Europe were described in Germany, France, Scandinavia and in the Czech Republic (Falkengren-Grerup

1986; Schulze et al. 1989; Soukopova, Rauch 1999; Thimonier et al. 1994). Eutrophication is only locally bound with enlargement of the amount of nitrogen and phosphorus, most often it is an increased supply of atmospheric nitrogen in the ammonium and nitrate form and its later mineralization in soil. With sulphur and its acidifying influence bound are, in many regions, the acidification processes, which are also influenced by nitrification processes taking place in conditions of nitrogen abundance. Both the processes exert a highly unfavourable influence on the Sudeten flora. Its connection with habitats, usually scanty of nutritive substances, formed predominantly on granites and gneiss, has been disturbed by supply of a pool of elements excess. Instead, acidification processes affect unfavourably the availability of the important for plants calcium, magnesium and potassium, and cause, at pH below 4.5, a liberation of considerable amounts of toxic aluminium. The shortage of magnesium, calcium and potassium, and the toxic action of aluminium are recognized as the direct cause of forest dieback in many European countries. In case of the Sudeten these trophic changes contribute to the degradation of sites of many mountain plants and favour the invasion of ubiquitous species which tolerate the low pH and the shortage of important life elements.

MATERIAL AND METHODS

The investigations were performed in 1990-1996 in the Śnieżnik massif and in the Karkonosze. The methods were described in detail in previous papers (Fabiszewski, Żołnierz 1992; Brej, Fabiszewski 1996).

The method was based on permanent plots, demarcated in the field especially for groups of rare species, mountain species, species known in the Sudeten as Carpathian species, for calcareous species and also for invasive species, particularly grasses. The contents of sulphur, nitrogen and its forms were assessed by means of the Autoanalyzer Braun-Luebe, soil acidity was assessed electrolytically. Heavy metals and aluminium were assessed by means of atomic absorption spectrophotometer – Spectrophotometer AA 200 Varian. Most of the assessments were performed on indirect material, using the existing bioindication methods, in this case – the cumulative abilities of peatmoss and lichens (Fabiszewski, Żołnierz 1992).

RESULTS AND DISCUSSION

Increased eutrophication of habitats alters the floristic composition

The eutrophication processes of habitats with nutritive components, particularly nitrogen and phosphorus, make the highest threat for the Sudeten flora. The geological structure of almost the whole mountain massif and the later developed soil cover formed here habitats scanty by nature in nutritive resources, particularly calcium and magnesium, and generally with an acid soil. Hence, almost the whole flora of the Sudeten (apart of Kaczawskie Mountains and other small fragments of that range) is represented by species, representatives of oligotrophic and acidophilous ecological groups. They do not tolerate, by nature, higher concentrations of calcium, nitrogen, phosphorus, potassium, and also compounds of these elements. Meanwhile, the developed in the Sudeten industry, the partially intense submontane agriculture (in the subalpine forests of the Karkonosze, Śnieżnik and in part of

Fig. 1. Differentiation of number of synanthropic species in examined area. 1 – plant species in villages and towns, 2 – plants invading higher mountains.

the Eastern Sudeten) carry into the habitats the mentioned above elements and compounds, and particularly recently, considerable amounts of nitrate forms. This contributes to diametrical changes in habitat fertility and preference of a set of species totally different than those developed during thousands of years in the natural, postglacial history of the flora and vegetation.

The quantitative share of synanthropic species in the area of the Śnieżnik massif and Bialskie Mountains is illustrated in Fig. 1, presenting the number of species accompanying man in the investigated towns and villages, and also anthropophytic plants in mountain areas. A top-level number of synanthropic species has been recorded on the clearing below the Śnieżnik (29) and on the mountain top of the Śnieżnik (22 species) which, as is well known, is a nature reservation. Distinctly lower numbers of synanthropic plants were recorded on mountain passes, among them the negatively distinguished Płoszczyna Pass (17 species). Among localities the highest number of synanthropic species has been recorded in Łądek (153) and Stronie Śląskie (141). Deep in the Bialskie Mts as much as 42 species grow in Gierałtów and 42 in the high-localized and for decades poorly inhabited village Bielice. Most species are concentrated along streams, home-, and farmsteads, and these are predominantly nitrophilous and phospho-

rophilous plants. It is interesting that the degree of synanthropisation in that part of the Sudeten is in line not only with the punctual contaminations, but also with nitrogen pollution. Its size in the mentioned area is presented in Fig. 2. These amounts, converted by means of bioindicator methods, so for the nitrate form and for total nitrogen, are the highest on the Śnieżnik mountain-top, the Mały Śnieżnik and below the Rudawiec in Bialskie Mountains. Nitrogen-fall values, lower almost by a half, have been noted at lower altitudes (except of the Biała Łądecka Valley). These data evidence the permanent role of long distance transport of nitrates to the Sudeten ecosystems and the threat of eutrophication, particularly in the exposed mountain areas. For example, in the Czech Karkonosze the nitrogen fall is about 50 kg (Soukopova et al. 1995), and in the clean – as is seen – Alps it is barely 8 kg/ha/year (Koerner 1995). The fertilization with nitrogen in the Sudeten brings vehement ecological results. This pertains mainly to such species which grew in nitrogen-poor habitats (e.g., on high mountain swards), to carbonate swards or to those which use rather the ammonium form of nitrogen (dwarf shrubs of *Ericaceae* family, crowberry, orchids and others) (Ulrich, Sumner 1991). The easily accessible nitrogen, particularly in the nitrate form, may – as results from recent studies (Aber et al. 1998) – inhibits the production of ectomy-

Fig. 2. Nitrate concentration (1) in Śnieżnik massif and Bialskie Mts calculated from concentration of two months exposed peat moss bundles and fall of total nitrogen (2) calculated (kg/ha/year) by measures of N in local growing *Polytrichum formosum* and *Hypogymnia physodes*. (Location of measure points as in Table 1).

corrhiza and endomycorrhiza in plants and may lead to the development of unfavourable soil bacteria. Such disturbances lead to changes in properties of soil and the decline of some plant species.

Eutrophication threats on structured areas come mainly from non-atmospheric sources, namely from the direct influence of man, who runs, among others, a thriftless and uncontrolled fertilisation and sewer management. Like in case of results on fall of nitrogen forms, an elevated content of heavy metals was found in the area of the Eastern Sudeten, emitted as dusts by various industrial plants. The accumulation of metals was studied also by bioindication methods (Table 1, Table 2). At this occasion confirmed were the previously known data (Fabiszewski, Żołnierz 1992) concerning the relatively high concentration of lead in plants in the Sudeten sites, and in some places also of zinc. We do not know all about the influence of many other metals upon the local natural flora. Having regard to the selective and cumulative character of metals uptake by plants, we may assume that the presented here values do not yet affect the flora and vegetation and whole ecosystems. However, some of the investigated elements, as for example the strongly elevated amount of lead (Stachurski et al. 1996) is considered as the causative metal in spruce-leaf chlorosis and has – according to the mentioned authors – its share in the decay of high mountain spruce forests. It is also known (Ashmore 1997) that many metals lower the activity of mycorrhizas in some species, and may also reduce the activity of soil microorganisms. The latter phenomena reduce probably the accessibility of habitats for various species. In the presented materials (Table 2) worthy of notice is also the high content of the toxic for plants aluminium (Lorenc-Plucińska 1996). It is found in considerable amounts accumulated in spruce leaves (ten times more than in the control leaves from the granite Tatra). This suggests a considerable presence of this element in bedrock (gneiss) and evidences also its liberation from soil in acidic environment, at pH below 4.2, which in the Sudeten ecosystems is not a rare phenomenon (particularly in high mountain spruce forests and high mountain swards). Some ecologists

(Ulrich, Sumner 1991) are inclined to ascribe to aluminium a leading role in spruce forest decay, but its direct action upon the particular plant species is still poorly known.

Progressing acidification eliminates the Sudeten Mountain flora

The main reason for acidification of the Sudeten plant habitats are the sulphur and nitrogen oxides emitted by coal industry. Its development in the years 1960-1980 caused huge gaseous and dust emissions, which affected above all coniferous forests in the whole Sudeten. The highest dosis of contamination was obtained by the Izerskie and Karkonosze Mountains. Somewhat later, in the eighties, the tragic results of industrialization affected the forests and the remaining ecosystems of the Eastern Sudeten. The rains acidifying all the Sudeten ecosystems is illustrated in Fig. 3., showing the content of total sulphur in plant materials from nine permanent plots in the Śnieżnik massif and its vicinity. The accumulation of sulphur is also high in the local lichen *Hypogymnia physodes*, which frequently reaches 2000 ppm. The highest acidification has been recorded in the Śnieżnik and Mały Śnieżnik, and in lower localized areas, in the Puszcza Jaworowa reserve and in Rogózka. The comparison of total sulphur content in spruce leaves in various regions of the Sudeten is presented in Fig. 4. As a background served here the data from high mountain forests for various age-groups of leaves from the granite Tatra (surroundings of the Hala Gąsienicowa). This figure depicts the stepwise increasing and decreasing sulphur content, highest in the Izerskie Mountains, intermediate in the Karkonosze, and relatively smaller in the area of the Śnieżnik. These values may in the Tatra be regarded as physiologically indifferent for plants, and they do not exceed the content of 1000 ppm.

Acid rains of sulphur and nitrogen forms affect unfavourably the changes of the soil environment in the whole Sudeten, causing a permanent, with different intensity in various areas, decrease of acidity in the toposoil. This process is illustrated by comparative investigations presented in Fig. 5. It reveals the decrease of the pH value in soils, even in cal-

TABLE 1. Concentration (ppm) of some heavy metals and aluminium in two-year spruce leaves in different parts (1-6) of examined area. Mean concentrations, n = 10, and standard errors are presented.

Site	Cu	Pb	Zn	Al
1. Śnieżnik	2.28 ± 0.31	4.80 ± 1.02	33.30 ± 3.75	118.14 ± 14.71
2. Pod Śnieżnikiem	2.08 ± 0.20	4.63 ± 1.00	37.17 ± 4.82	121.70 ± 17.72
3. Mały Śnieżnik	2.14 ± 0.23	3.98 ± 0.48	31.02 ± 3.12	98.42 ± 14.12
4. Puszcza Jaworowa	1.74 ± 0.31	1.92 ± 0.40	28.03 ± 2.93	99.14 ± 8.12
5. Kletno	1.14 ± 0.24	1.17 ± 0.18	23.75 ± 6.74	13.24 ± 2.28
6. Rogózka	2.70 ± 0.23	2.30 ± 0.20	21.24 ± 3.27	15.28 ± 2.87

TABLE 2. Concentration (ppm) of some heavy metals in *Polytrichum formosum* growing in different parts (1-9) of examined area. Mean concentrations, n = 6-8, and standard errors are presented.

Site	Cd	Cu	Fe	Ni	Pb	Zn
1. Śnieżnik	0.99 ± 0.13	14.03 ± 0.80	342 ± 51	2.72 ± 0.70	37.42 ± 7.00	58.64 ± 7.20
2. Pod Śnieżnikiem	0.82 ± 0.10	12.00 ± 0.70	503 ± 49	2.99 ± 0.79	42.37 ± 6.80	59.39 ± 7.80
3. Mały Śnieżnik	0.59 ± 0.12	12.09 ± 0.83	427 ± 32	1.87 ± 0.90	38.02 ± 6.70	53.48 ± 6.20
4. Puszcza Jaworowa	0.49 ± 0.08	11.70 ± 0.49	329 ± 17	1.73 ± 0.88	35.70 ± 5.89	51.42 ± 3.70
5. Jaworowa Kopa	0.40 ± 0.07	12.40 ± 0.63	384 ± 17	1.08 ± 0.70	39.76 ± 5.49	52.01 ± 4.20
6. Kamienica	0.32 ± 0.02	10.48 ± 1.20	327 ± 19	1.24 ± 0.60	37.40 ± 6.00	46.30 ± 4.80
7. Czernica	0.22 ± 0.03	9.01 ± 1.70	349 ± 22	0.50 ± 0.03	38.47 ± 7.20	49.10 ± 7.30
8. Kletno	0.41 ± 0.05	10.27 ± 2.25	282 ± 26	1.80 ± 0.60	29.90 ± 6.65	52.80 ± 7.60
9. Rogózka	0.20 ± 0.02	8.47 ± 1.25	214 ± 16	śląd	21.80 ± 1.31	50.63 ± 7.20

Fig. 3. Total sulphur concentration in 3-years old spruce leaves (1), in locally growing *Hypogymnia physodes* (2) and in exposed during two months peat moss bundles (3). (Location of measure points as in Table 1).

careous areas (Klesnica valley under the Śnieżnik), where the shallow soil is not able to buffer the external acidity. The ongoing there chemical conversions suit the needs of acidophilous plants and, to some extent, tend towards acceptance of wider limits of tolerance by the local calciphilous flora. The pH values 7.0-7.9 recorded in 1969 are not found in this days, and the old forests with *Elymus europaeus* and *Cardamine trifolia* changed into acidophilous beech forests with dominating *Deschampsia flexuosa*. This is almost a school-bookish evidence for the existence of acidification processes in the Sudeten. The changes in species composition of the Karkonosze subalpine swards from 1959 (investigations by W. Matuszkiewicz and A. Matuszkiewicz 1969, manuscript) until

Fig. 4. Comparison of total sulphur concentration in spruce leaves (1-4 yr old) growing in Śnieżnik massif, Izerskie, Karkonosze and Tatra Mts.

the nineties, are illustrated in Figs 6 and 7 (Wojtuń et al. 1994). These show a drastic decline of dwarf shrubs in various regions of the Karkonosze caused by the invasion of grasses. This kind of changes is presented in many papers (Dähler 1992; Hegg 1992). Similar changes, on a local scale, were also investigated on the mountain-top of the Śnieżnik (Brej, Fabiszewski 1996), they are presented in Fig. 8. This figure shows the changes in species diversity, dependent on the elimination of dwarf shrub communities and rich in

Fig. 5. Decrease of pH in humus soil layer during the last 25-years in Klesnica Valley (Śnieżnik massif).

Vaccinium vitis-idaea *Vaccinium myrtillus* *Calluna vulgaris*

■ 1959 □ 1993

Carex bigelowii subsp. *rigida* *Deschampsia flexuosa* *Anthoxanthum odoratum*

■ 1959 □ 1993

Fig. 6. Cover coefficient (D) of three dwarf shrubs growing in subalpine swards *Carici-Nardetum* in the Karkonosze Mts during 1959-1963 (Wojtuń et al. 1994).

Fig. 7. Cover of grasses (coefficient D) expanding in subalpine swards *Carici-Nardetum* during 1959-1963 (Wojtuń et al. 1994).

mountain species of subalpine grassland for the benefit of the intensely invading *Deschampsia flexuosa* and *Calamagrostis villosa*.

The disturbances in natural mineral composition of habitats reduce floristic diversity

The results of earlier investigations (Fabiszewski, Brej 1992; Fabiszewski, Wojtuń 1994) confirmed the general acidification of soil in all the Sudeten ranges. The soil acidity decreased during the last 30 years on the average by 0.5-1.0 pH. The external factors of acidification are mainly inorganic acids H_2SO_4 and HNO_3 , the source of which is gaseous and dust pollution. The acidification of the Sudeten habitats is also accompanied by other soil processes unfavourable for plants. These are, above all, the inaccessibility or washing out of alkaline cations, mainly calcium, magnesium and potassium. Many plants in the described terrain are badly in need of calcium and magnesium, which occur only in small amounts in the soil cover. Recently the particularly negative reaction of plants to shortage of calcium has been described (DeHayes et al. 1999) the deficite of which arises in conditions of acid rains and with decrease of pH value in soil. The changes start at cell level and end with the disappearance of specimens and diminution of plant ranges. As mentioned ear-

lier, in the acidified Sudeten soils an increase in mobility of exchangeable aluminium was recorded, the excess of which is particularly harmful, because it acts toxically upon the roots of many plants, including also the spruce and fir. The shortage of calcium, magnesium and potassium and the toxic action of aluminium are recognized as the direct causes of extinction of many vascular plant species, including also the fir and the spruce (Schulze et al. 1989; Ulrich, Sumner 1991; Abrahamsen et al. 1994). The retreat of many other oligotrophic plants is interrelated with the growing availability of nitrogen in soil, particularly of its nitrate form (Hegg 1992; Johanson, Lindberg 1992). The still lasting overfertilization with nitrogen, the reduction of soil activity and the shortage of essential elements promote the invasion of several grass species. Their pressure causes the retreat of the competitively weaker mountain species, mainly forming the components of subalpine swards, subalpine grasslands and high mountain spruce forest in the Karkonosze and the Śnieżnik Mtn. Examples of local flora retreat as a result of soil changes and the connected with it aggressive invasion of grasses in the Śnieżnik massif are given in Table 3. The expansion of grasses, particularly *Deschampsia flexuosa* and *Calamagrostis villosa*, is at present a common phenomenon in many Sudeten plant associations (Fabiszewski, Wojtuń 1994). In the forest

Fig. 8. Plant biodiversity decreasing on the top of Sněžník Mt. during a quarter of a century. 1 – conspicuous patches of heaths *Vaccinietum myrtilli*, in 1969; 2 – conspicuous patches of subalpine dwarf shrub heaths *Empetro-Vaccinietum*, in 1969; 3 – conspicuous patches of Hawks-beards subalpine grassland *Crepidi-Calamagrostietum*, in 1969; 4 – nitrophilous and trodden ground vegetation; 5 – dense range of *Deschampsia flexuosa* in 1994; 6 – dense distribution of *Calamagrostis villosa*, in 1994, eliminating previous mountain dwarf shrub and sward communities.

TABLE 3. Some examples of invasive and declining species connected with contemporary habitat changes in the Sudety Mts. Nomenclature according to Mirek et al. 1995. SM – Sněžník massif; K – Karkonosze Mts.

	Eutrophication	Acidification
<u>Invasive plants</u>		
<i>Deschampsia flexuosa</i>	+	+
<i>Calamagrostis villosa</i>		+
<i>C. arundinacea</i>		+
<i>Anthoxanthum odoratum</i>		+
<i>Carex bigelowii</i> ssp. <i>rigida</i>		+
<i>Mimulus guttatus</i>	+	
<i>Rumex alpinus</i>	+	
<i>Senecio fuchsi</i> + <i>S. nemorensis</i>	+	
<i>Chamaenerion angustifolium</i>	+	
<i>Athyrium distentifolium</i>	+	
<u>Declining plants</u>		
<i>Campanula barbata</i> (SM)	+	
<i>Delphinium elatum</i> (SM)	+	
<i>Polystichum braunii</i> (SM)		+
<i>Diphasiastrum alpinum</i>		+
<i>Huperzia selago</i>		+
<i>Euphorbia amygdaloides</i> (SM)		+
<i>Epipactis atrorubens</i>		+
<i>Pulsatilla alba</i> (K)		+
<i>Anemone narcissiflora</i> (K)		+
<i>Primula minima</i> (K)		+
<i>Hieracium alpinum</i>		+
<i>Homogyne alpina</i> (SM)		+
<i>Luzula sudetica</i> (K)		+
<i>Arnica montana</i>		+
<i>Listera cordata</i>		+
<i>Moneses uniflora</i>		+
<i>Hieracium aurantiacum</i>		+
<i>Crepis conyzifolia</i>		+
<i>Empetrum nigrum</i> (K)		+

floor of the Karkonosze high mountain spruce forest recorded was a fivefold increase in the share of these species, as compared to the state existing thirty years before (Matuszkiewicz, Matuszkiewicz 1969; Fabiszewski, Brej 1992; Fabiszewski et al. 1993; Żołniercz et al. 1994). The mass-development of grasses occurs particularly distinctly on the degraded, deforested surfaces in the high mountain belt of the Sudeten (Fabiszewski, Wojtuń 1994). Similar phenomena are observed also over the mountain forest belt. For example, in the subalpine swards of the Karkonosze subalpine forest recorded was a three – fourfold increase of the *Deschampsia flexuosa* and *Anthoxanthum odoratum* cover, and a twofold increase of the *Calamagrostis villosa* cover, and as much as a fivefold increase of the quantitative share of sedge *Carex bigelowii* ssp. *rigida* (Wojtuń et al. 1994).

CONCLUSIONS

During the last forty years there occurred a considerable rebuilding of the species structure in most of the Sudeten phytocoenoses. The changes in flora and vegetation are mainly connected with changes taking place in the Sudeten soil under the influence of eutrophication and acidification. The main eutrophication elements are nitrogen and phosphorus, the fertilization with which contributes to the invasion of nitrophilous and cosmopolitic plants. The acidification of habitats through decrease of pH causes the diminution of calcium, magnesium and potassium in soil, leading to undernutrition of plants. In conditions of a very low acidity the exchangeable aluminium – an element toxic for many species – is liberated. In result of the described changes and particularly because of habitat enrichment, during the last decade, in mineral forms of nitrogen, the most perceptible changes in the Sudeten flora and vegetation consist in the following phenomena:

(1) expansion of several species of common grasses (particularly *Deschampsia flexuosa*, *Calamagrostis villosa* and *Anthoxanthum odoratum*) in all the mountain belts

(2) retreat of plant families Ericaceae and Empetraceae from subalpine swards

(3) decline of typical mountain vascular plants like: *Diphasiastrum alpinum*, *Huperzia selago*, *Luzula sudetica*, *Pulsatilla alpina*, *Anemone narcissiflora*, *Primula minima*, *Hieracium alpinum*

(4) total extermination of epiphytic lichens and bryophytes, except of several cosmopolitic species

(5) diminution of the quantitative share of certain terricolous bryophytes and lichens like *Polytrichum formosum*, *Cetraria* spp. div.

(6) vegetation vulgarization through penetration high into the mountains of ubiquitous species and typical synanthropic plants.

LITERATURE CITED

- ABER J. et al. 1998. Nitrogen saturation in temperate forest ecosystems. *BioScience* 48: 921-934.
- ABRAHAMSEN G. et al. (eds). 1994. Long-term experiments with acid rain in the Norwegian forest ecosystems. *Ecological Studies* 104: 1-342.
- ASHMORE M. 1997. Plants and pollution. In: M.J. CRAWLEY (ed.). *Plant Ecology*, pp. 568-581. Blackwell Sci. Publ., Oxford.
- BREJ T., FABISZEWSKI J. 1996. Śnieżnik i pobliskie masywy górskie jako ostoje różnorodności roślinnej. *Ann. Silesiae* 26: 7-25.
- BREJ T., FABISZEWSKI J. 1997. Zmiany antropogeniczne różnorodności roślinnej w masywie Śnieżnika. *Ann. Silesiae* 27: 63-74.
- DÄHLER W. 1992. Long term influence of fertilization in a *Nardetum*. The management of great quantities of data from permanent plots. *Vegetatio* 103: 141-150.
- DEHAYES D.H. et al. 1999. Acid rain impacts on calcium nutrition and forest health. *BioScience* 49: 789-800.
- FABISZEWSKI J., BREJ T. 1992. Some ecological consequences of forest decline in the Sudety Mts. *Botanikeratung* 13, bis 19, pp. 201-202, Berlin.
- FABISZEWSKI J., BREJ T. 1996. Dynamika przemian flory i roślinności. In: A. JAHN et al. (eds.), *Masyw Śnieżnika – zmiany w środowisku przyrodniczym*, pp. 221-228. Polska Agencja Ekologiczna, Warszawa.
- FABISZEWSKI J., WOJTUŃ B. 1994. Zjawiska ekologiczne towarzyszące wymieraniu lasów w Sudetach. *Prace IBL* 21, ser. B: 195-210.
- FABISZEWSKI J., ŻOŁNIERZ L. 1992. Rozkład skażeń siarką i metalami ciężkimi w regionie sudeckim, określony metodami bioindykacyjnymi. *Ann. Silesiae* 22: 15-28.
- FABISZEWSKI J. et al. 1993. Zmiany ilościowe roślin runa sudeckiego boru górnoeglowego o różnym stopniu degradacji. In: *Karkonoskie Badania Ekologiczne*, pp. 77-85. Oficyna Wydawnicza Instytutu Ekologii PAN.
- FALKENGEREN-GRERUP U. 1986. Soil acidification and vegetation changes in deciduous forest in southern Sweden. *Oecologia (Berlin)* 70: 339-347.
- HEGG O. 1992. Long term influence of fertilization in a *Nardetum*. Experimental field of Dr. W. Lüdi on Schynige Platte. *Vegetatio* 103: 133-137.
- JOHNSON D.W., LINDBERG S.E. (eds). 1992. Atmospheric deposition and forest nutrient cycling. *Ecological Studies* 91: 1-707.
- KOERNER CH. 1995. Impact of atmospheric changes in Alpine vegetation: the ecophysiological perspectives. *Conserv. Jard. Genève*, pp. 113-120.
- LORENC-PLUCIŃSKA G. 1994. Fizjologiczne i biochemiczne aspekty oddziaływania glinu na rośliny. In: *Reakcje biologiczne drzew na zanieczyszczenia przemysłowe*, III Krajowe Symposium, Kórnik, pp. 465-469.
- MATUSZKIEWICZ W., MATUSZKIEWICZ A. 1969. Mapa roślinności naturalnej Karkonoskiego Parku Narodowego. Manuscript, 213 pp.
- MIREK Z. et al. 1995. Vascular plants of Poland – a checklist. Polish Academy of Sciences. W. Szafer Institut of Botany, Kraków, 308 pp.
- SCHULZE E.-D. et al. (eds). 1989. Forest decline and air pollution. *Ecological Studies* 77: 1-475.
- SOUKOPOVA L., RAUCH O. 1999. Floor vegetation and soil acidified *Picea abies* forests in the Giant Mountains (Central Europe). *Preslia* 71: 257-275.
- SOUKOPOVA L. et al. 1995. Arctic – alpine tundra in the Karkonoše, the Sudetes. *Opera Corcontica* 32: 5-88.
- STACHURSKI A. et al. 1994. Próba oceny przyczyn powstawania chloroz liściowych u świerka (*Picea abies*) w Karkonoszach. In: *Reakcje biologiczne drzew na zanieczyszczenia przemysłowe*, III Krajowe Sympozjum, Kórnik, pp. 407-414.
- THIMONIER A. et al. 1994. Simultaneous eutrophication and acidification of a forest ecosystem in north – east France. *New Phytologist* 126: 533-539.
- ULRICH B., SUMNER M.E. (eds). 1991. *Soil Acidity*. Springer Verlag, Berlin, pp. 224.
- WOJTUŃ B. et al. 1994. Zmiany jakościowe i ilościowe flory muraw bliźniczkowych (*Carici-Nardetum*) w Karkonoszach na przestrzeni ostatnich 40 lat. In: *Karkonoskie Badania Ekologiczne*, pp. 163-180. Oficyna Wydawnicza Instytutu Ekologii PAN.
- ŻOŁNIERZ L. et al. 1994. Zmiany ilościowe i jakościowe roślinności na powierzchniach o różnym czasie wylesienia w piętrze górnoeglowym Karkonoszy. In: *Karkonoskie Badania Ekologiczne*, pp. 153-161. Oficyna Wydawnicza Instytutu Ekologii PAN.

WSPÓŁCZESNE ZMIANY FLORYSTYCZNE I SIEDLISKOWE W SUDETACH

STRESZCZENIE

Od czterdziestu lat w obszarze Sudetów, wskutek emisji przemysłowych, przebiegają równoległe procesy eutrofizacji i acidyfikacji. Przedstawiono wyniki badań bioindykacyjnych nad opadem i kumulacją siarkę, azotu i metali ciężkich. Badano przemiany flory i roślinności po trzydziestu latach, na stałych powierzchniach na Śnieżniku i w Karkonoszach. Stwierdzono spadek pH w większości siedlisk do ponad 1.0. Kwaśne opady, zawierające dużo azotanów przyczyniają się do użyźnienia większości ekosystemów. Roczny opad azotu całkowitego wynosi w Sudetach: od 38 kg w Karkonoszach do 59 kg/ha na Śnieżniku, azotanów – od 380 do 900 ppm/rok, a siarki ogólnej średnio 130 ppm rocznie. Zakwaszenie gleby powoduje niedostępność pierwiastków alkalicznych (magnez, wapń) oraz uruchamianie szkodliwego dla roślin glinu. Przenawożenie siedlisk, brak wapnia i magnezu oraz nadmiar glinu powodują niekorzystne przemiany we wszystkich fitocenozach sudeckich.

SŁOWA KLUCZOWE: eutrofizacja, acidyfikacja, Sudety, skażenia atmosferyczne, spadek bioróżnorodności.