POLISH POLAR RESEARCH	21	1	43–54	2000

Zbigniew JÓŹWIK

Department of Plant Physiology
Maria Curie-Skłodowska University
Akademicka 19
20-033 Lublin, POLAND

Heavy metals in tundra plants of the Bellsund in West Spitsbergen, investigated in the years 1987–1995

ABSTRACT: In the years 1987–1995 studies were carried out on the content of Cu, Mn, Zn, Pb and Cd in plants and soil in the Bellsund area, Western Spitsbergen. For the studies the author used predominating species of vascular plants, bryophytes and lichens collected from beaches littoral planes, valleys, slopes and mountain peaks. Some plant species, largely bryophytes and lichens, were shown to contain increased amounts of Zn, Pb and Cd, whilst in others Cu deficiency was found. This paper is summing up studies concerning the content of Cu, Mn, Zn, Pb and Cd in plants of Western Spitsbergen, which were conducted over many years.

Key words: Arctica, Spitsbergen, plants, heavy metals.

Material

The studies comprised 22 species of vascular plants (Table 1), 25 species of bryophytes (Table 2) and 13 species of lichens (Table 3). From several to over a dozen specimens of each species were collected from the particular tundra plant patches in various stands. The material was dried, ground in agate mortars, well mixed, determining its dry weight. Plant samples were taken in July and August of 1987, 1989, 1991, 1993 and 1995.

Study area

Studies were carried out during the successive expeditions to Spitsbergen in Bellsund area on the fiord Recherche. Plants were collected on the littoral planes:

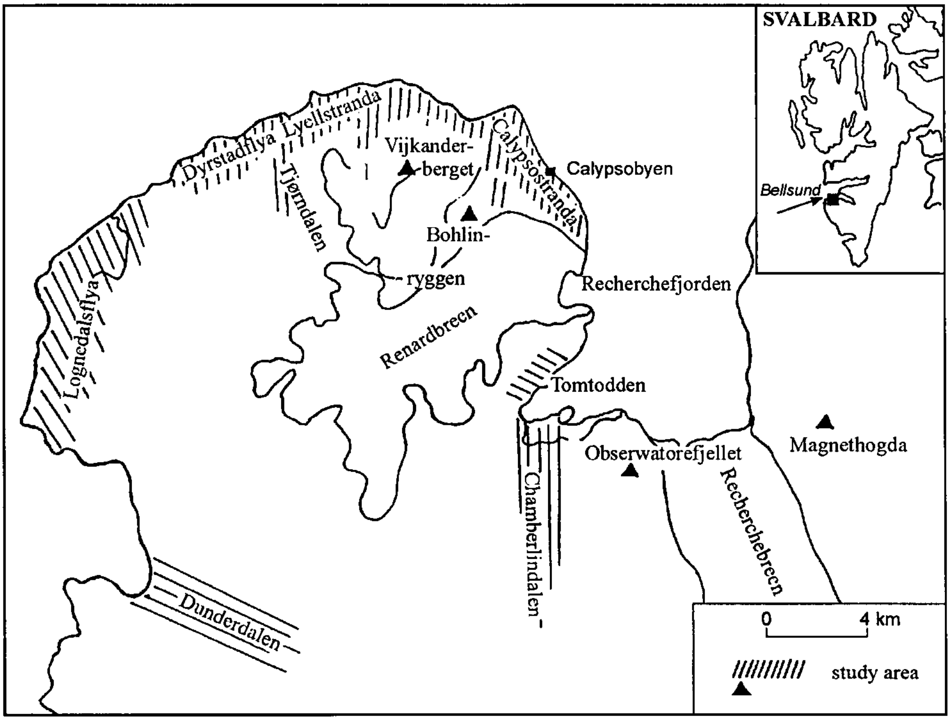

Fig. 1. Places of plant collection: Bellsund area (Western Spitsbergen).

Calypsostranda, Lyellstranda, Dyrstadflya, Lognedalsflya and Tomtodden; in the valleys: Chamberlindalen, Tjørndalen, and Dunderdalen; on the mountain slopes and peaks: Wijkanderberget, Bohlinryggen, Observatoriefjellet and Magnethøgda (Fig. 1). These studies were a part of the programme of scientific expeditions to Spitsbergen organized by the Maria Curie-Skłodowska University in Lublin. The obtained results were published in scientific journals and collective works (see Jóźwik 1990 a,b, 1991, 1992, 1999; Jóźwik and Magierski 1991, 1992, 1993, 1994, 1995).

Methods

The content of Cu, Mn, Zn, Pb and Cd in plant samples was determined on an atomic absorption spectrophotometer Pye Unicam SP 9 as a result of flame excitation. The plant material was incinerated in a mixture of nitric (63%) and perchloric acid (60%) at 7:1 ratio (v/v). A control test was also made for the used reagents and distilled water.

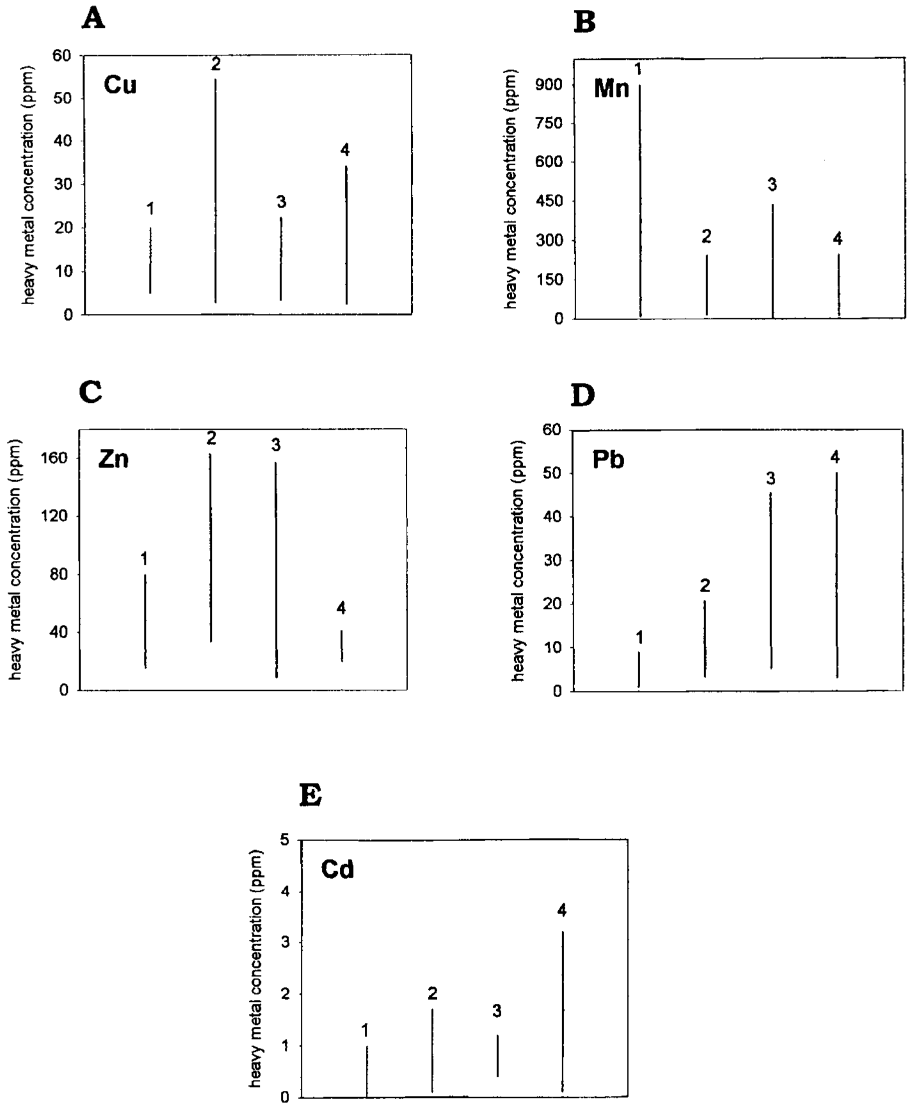

Fig. 2. Heavy metals in tundra plants (ppm) of West Spitsbergen, the Bellsund area. Studies of the years 1987–1995. 1 – average content of heavy metals in plants (ppm) according to Kabata-Pendias and Pendias (1979); 2 – average content of heavy metals in vascular plants (ppm); 3 – average content of heavy metals in bryophytes (ppm); 4 – average content of heavy metals in lichens (ppm).

Results and discussion

From the obtained results it can be found that some of the examined plants showed a big tolerance to accumulated metals to which Pb, Zn and Cd belong. Their

Table 1

Mean content of heavy metals in vascular plants (ppm). Studies of the years 1987–1995.

Species	Cu	Mn	Zn	Pb	Cd
Carex misandra	6.3	199.8	27.9	3.9	0.2
Cerastium arcticum	11.7	78.3	$\boxed{97.4}$	$\boxed{15.2}$	0.9
Cochlearia groelandica	54.5	27.2	83.4	4.1	$\boxed{1.2}$
C. officinalis	$\textcircled{3.7}$	111.6	58.3	$\boxed{13.5}$	0.2
Deschampsia alpina	7.4	91.6	48.2	4.5	0.4
Draba corymbosa	11.5	13.1	97.5	$\boxed{13.9}$	0.3
Dryas octopetala	5.4	79.8	43.9	$\boxed{12.4}$	0.5
Equisetum arvense	6.1	26.5	79.9	–	–
Luzula arctica	$\textcircled{4.8}$	156.0	91.9	$\boxed{13.9}$	0.4
Oxyria digina	$\textcircled{4.8}$	192.4	51.2	7.9	0.5
Papaver dahlianum	6.3	113.1	51.9	3.6	0.8
Poa alpina	5.4	16.5	61.4	3.2	0.6
Polygonum viviparum	$\textcircled{2.7}$	71.0	40.8	$\boxed{10.6}$	0.8
Salix polaris	6.3	86.9	$\boxed{163.2}$	$\boxed{10.4}$	$\boxed{1.7}$
S. reticulata	4.9	46.1	$\boxed{159.4}$	$\boxed{16.1}$	0.7
Saxifraga aizoides	$\textcircled{3.5}$	60.0	33.8	$\boxed{20.6}$	0.8
S. caespifosa	5.7	51.4	72.7	8.2	$\boxed{1.1}$
S. cernua	$\textcircled{4.1}$	54.8	32.4	$\boxed{15.1}$	0.1
S. flagellaris	$\textcircled{4.1}$	104.5	82.2	7.6	0.6
S. hirculus	5.5	171.2	$\boxed{155.9}$	7.3	$\boxed{1.2}$
S.oppositifolia	$\textcircled{4.0}$	51.5	45.0	$\boxed{10.0}$	0.6
Silene acaulis	$\textcircled{4.5}$	243.4	33.2	$\boxed{11.5}$	$\boxed{1.1}$

○ metal concentration below its physiological level

□ metal concentration exceeding its mean level described in literature
SE values for vascular plants are 3-50% (n = 4–56)

occurence in excess as regards Pb, and at excessive physiological concentrations in the case of Zn, can account for natural environment pollution with these metals in the area investigated. On the other hand Cu deficiency was found both in vascular plants and bryophytes and also in lichens. This may have been caused by a smaller content of the metal in soils of Spitsbergen, which was found from soil analysis in the studied area (Jóźwik and Magierski 1993). It my also result from diminished demand of the studied species for this metal or inability of the examined plants to accumulate Cu.

It is difficult to discuss in this paper every plant analysed in the successive years and present hundreds of the obtained results. Thus it was decided to present the mean results of five years of studies conducted in Spitsbergen every second year. They are listed in tables showing the content of Cu, Mn, Zn, Pb and Cd in the particular species of vascular plants, bryophytes and lichens (Tables 1–3). The

Table 2

Mean concent of heavy metals in bryophytes (ppm). Studies of the years 1987–1995.

Species	Cu	Mn	Zn	Pb	Cd
Aulacomnium palustre	19.3	248.1	53.5	$\boxed{23.0}$	0.5
A. turgidum	5.3	131.4	63.1	6.2	0.6
Bryum crithatum	22.3	356.0	$\boxed{157.0}$	$\boxed{38.8}$	0.8
B. cryophilum	8.3	234.7	14.8	$\boxed{10.2}$	0.6
B. elegans	5.6	215.4	55.5	8.4	0.9
B. schleicheri var. latifolium	6.5	16.5	62.5	3.9	1.0
Camphylium polygamum	16.8	132.2	85.6	$\boxed{18.6}$	0.4
Catoscopium nigritum	12.0	52.3	63.5	$\boxed{30.0}$	0.5
Dicranoweissia crispula	9.6	142.8	51.4	$\boxed{27.7}$	0.4
Dicranum bonjeanii	13.3	4.2	41.6	5.0	0.9
D. elongatum	$\enclose{circle}{4.4}$	51.2	79.8	$\boxed{26.5}$	0.7
D. fuscences	$\enclose{circle}{3.5}$	54.9	34.7	$\boxed{9.7}$	0.5
Distichium capillaceum	$\enclose{circle}{4.1}$	92.3	24.8	$\boxed{23.2}$	0.6
Drepanocladus fluitans	15.3	254.0	$\enclose{circle}{8.4}$	$\boxed{13.2}$	0.8
D. revolvens	6.8	219.3	40.4	$\boxed{17.7}$	0.7
D. uncinatus	7.6	39.9	65.8	$\boxed{12.4}$	0.7
Hylocomium splendens	8.5	48.1	45.0	$\boxed{24.9}$	0.7
Onocophorus wahlenbergii	5.9	144.5	53.9	$\boxed{21.5}$	$\boxed{1.1}$
Pohlia cruda	12.8	111.5	37.0	$\boxed{14.5}$	0.5
P. polymorpha	8.8	142.2	$\boxed{101.0}$	$\boxed{12.0}$	0.5
Ptilidium ciliare	$\enclose{circle}{3.2}$	144.5	53.9	$\boxed{21.5}$	$\boxed{1.1}$
Racomitrium lanuginosum	$\enclose{circle}{3.9}$	78.5	38.4	$\boxed{14.6}$	0.6
Schistidium apocarpum	6.7	435.3	49.3	$\boxed{45.6}$	$\boxed{1.2}$
Sphagnum squarrosum	6.1	37.6	47.4	$\boxed{11.7}$	0.8
Tetralophozia setiformis	$\enclose{circle}{3.6}$	47.2	45.0	$\boxed{12.0}$	0.5

◯ metal concentration below its physiological level

□ metal concentration exceeding its mean level described in literature
SE values for bryophyta are 3–24% (n = 4–28)

content of these elements in the selected species with regard to the places of their collection is shown in Table 4a–h. The selection of the species dependent on their constant occurrence in the geomorphologically differentiated area. Such a presentation procedure allows us to obtain a characteristic of the particular plant species and determine the very differentiated places of their occurrence (Święs 1988). Table 4a–h and their graphical interpretation (Fig. 2a–e) show the occurrence range of the analysed metals in the particular plant groups, comparing the obtained concentrations of the metals with their mean values in plants on the basis of the monography of Kabata-Pendias and Pendias (1993). Metals in each sample were

Table 3

Mean content of heavy metals in lichens (ppm). Studies of the yeras 1987–1995.

Species	Cu	Mn	Zn	Pb	Cd
Cetraria crispa	(3.1)	13.0	19.0	$\boxed{22.5}$	0.1
C. hiascens	(2.3)	21.9	34.7	$\boxed{21.7}$	0.5
C. nivalis	(3.1)	13.3	28.6	$\boxed{10.5}$	0.9
Cladonia gracilis	(4.4)	15.5	39.5	$\boxed{26.2}$	$\boxed{1.4}$
C. mitis	(3.9)	22.6	28.4	7.9	0.5
Ochrolechia frigida	10.1	244.5	68.2	$\boxed{50.0}$	$\boxed{1.4}$
Parmelia sp.	12.9	57.0	29.0	$\boxed{40.2}$	0.7
Peltigera sp.	11.0	11.2	35.3	7.5	1.0
Stereocaulon denudatum	6.0	47.6	24.6	$\boxed{26.0}$	$\boxed{3.2}$
Stereocaulon sp.	(3.5)	25.7	20.0	$\boxed{16.6}$	0.4
Thamnolia vernicularis	(2.9)	9.6	35.1	$\boxed{11.7}$	0.8
Umbilicaria sp.	34.0	14.2	41.2	$\boxed{17.2}$	0.7
Xantoria elegans	5.5	27.1	36.2	3.0	$\boxed{1.7}$

◯ metal concentration below its physiological level

□ metal concentration exceeding its mean level described in literature
SE values for lichens are 2-20% (n = 4–30)

determined three times in the given research period, and the number of samples of the individual plant species was from 4–56. Arithmetic mean values for five research periods are presented in the tables. The SE values were from several to about 50%. This is connected with the fact of differentiated accumulation of elements in different places of taking plant samples. It is related largely to Mn and Pb.

Cu content

The average Cu content in plants ranged from 5–20 ppm accorrding to the literature. In the author's analysis of plants of West Spitsbergen a deficiency of this element was found in some of them, to which in the vascular group belong: *Cochlearia officinalis* – 3.7 ppm, *Luzula arctica* – 4.8 ppm, *Oxyria digina* – 4.8 ppm, *Polygonum viviparum* – 2.7 ppm, *Salix reticulata* – 4.9 ppm, *Saxifraga aizoides* – 3.5 ppm, *S. cernua* – 4.1 ppm, *S. flagellaris* – 4.1 ppm, S. oppositifolia – 4.0 ppm and *Silene acaulis* – 4.5 ppm.

Among bryophytes Cu deficiency was found in: *Dicranum elongatum* – 4.4 ppm, *D. fuscescens* – 3.5 ppm, *Distichium capillaceum* – 4.1 ppm, *Racomitrium lanuginosum* – 3.9 ppm and *Tetralophozia setiformis* – 3.6 ppm.

Among lichens Cu deficiency was found in: *Cetraria crispa* – 3.1 ppm, *C. hiascens* – 2.3 ppm, *C. gracilis* – 4.4 ppm, *Cladonia mitis* – 3.9 ppm, *Stereocaulon sp.* – 3.5 ppm and *Thamnolia vernicularis* – 2.9 ppm.

Table 4a–h

Content of heavy metals in selected plant species in regard to places of collection (ppm). Studies of the years 1987–1995.

4a. *Salix polaris*

Place of collection	Cu	Mn	Zn	Pb	Cd
Calypsostranda	7.2	59.9	170.9	7.8	2.0
Lyellstranda	6.0	71.9	111.1	18.6	0.6
Tjørndalen	4.4	56.3	–	6.1	0.8
Dyrstadflya	4.0	82.5	129.5	4.8	1.3
Lognedalsflya	3.2	28.3	114.8	3.2	1.5
Chamberlindalen	9.3	228.8	210.6	41.0	1.2
Dunderdalen	6.0	143.0	171.2	1.2	2.6
Wijkanderberget	2.4	106.2	169.9	–	2.4
Bohlinryggen	3.8	84.2	296.5	–	9.5
Obervatoriefjellet	7.3	177.5	171.0	4.7	1.8
Magnethøgda	11.8	115.7	203.8	15.3	0.7

4b. *Dryas octopetala*

Place of collection	Cu	Mn	Zn	Pb	Cd
Calypsostranda	6.4	131.2	48.8	17.0	0.7
Lyellstranda	5.6	51.4	25.2	35.3	–
Tjørndalen	6.2	31.0	49.2	8.2	0.2
Dyrstadflya	3.6	20.5	23.6	7.4	0.3
Lognedalsflya	3.7	38.0	29.0	6.4	0.3
Tomtodden	4.1	49.2	64.0	7.0	0.5
Chamberlindalen	6.9	32.0	35.0	6.5	0.4
Bohlinryggen	2.6	45.7	30.8	1.3	0.3
Obervatoriefjellet	5.1	103.0	80.0	9.1	0.4
Magnethøgda	4.7	28.4	39.9	8.5	0.3

4c. *Saxifraga oppositifolia*

Place of collection	Cu	Mn	Zn	Pb	Cd
Calypsostranda	4.5	45.2	56.5	15.8	0.6
Lyellstranda	6.1	48.6	23.8	14.3	0.7
Tjørndalen	3.3	41.9	36.0	8.9	0.3
Dyrstadflya	4.3	25.9	18.9	9.1	0.5
Lognedalsflya	2.1	21.0	15.8	6.6	0.4
Tomtodden	2.4	14.2	61.5	0.5	0.5
Chamberlindalen	7.1	20.5	15.3	3.9	0.4
Dunderdalen	5.2	98.9	78.6	2.9	0.9
Wijkanderberget	2.2	64.4	44.3	1.9	0.8
Bohlinryggen	2.3	51.3	19.8	4.1	0.5
Obervatoriefjellet	8.4	172.5	82.5	11.2	0.5
Magnethøgda	2.2	6.4	18.9	9.9	0.5

4d. *Saxifraga caespitosa*

Place of collection	Cu	Mn	Zn	Pb	Cd
Calypsostranda	6.6	60.1	64.0	$\boxed{11.6}$	0.4
Lognedalsflya	2.8	24.0	34.6	5.6	0.5
Dunderdalen	7.4	34.8	97.6	4.4	$\boxed{1.1}$
Chamberlindalen	2.2	38.0	16.0	6.1	0.4
Tomodden	3.6	17.2	95.0	1.5	0.5
Obervatoriefjellet	5.8	96.8	$\boxed{113.5}$	7.1	0.5
Wijkanderberget	2.1	57.3	67.0	–	$\boxed{1.8}$

4e. *Silene acaulis*

Place of collection	Cu	Mn	Zn	Pb	Cd
Calypsostranda	5.1	284.4	28.8	$\boxed{13.6}$	1.4
Lyellstranda	3.6	304.8	25.7	$\boxed{14.5}$	0.6
Tjørndalen	4.1	435.4	14.4	$\boxed{14.1}$	0.3
Dyrstadflya	2.9	33.4	22.0	$\boxed{12.6}$	1.2
Tomtodden	4.6	92.7	78.5	3.0	0.7
Chamberlindalen	4.6	215.5	21.0	9.3	0.4
Dunderdalen	5.4	144.5	50.9	4.2	$\boxed{1.7}$
Bohlinryggen	1.5	616.7	13.0	4.6	1.0
Obervatoriefjellet	5.4	213.7	$\boxed{99.3}$	$\boxed{16.7}$	$\boxed{1.5}$
Magnethøgda	3.3	139.1	17.6	$\boxed{13.9}$	0.2

4f. *Certaria hiascens*

Place of collection	Cu	Mn	Zn	Pb	Cd
Calypsostranda	2.6	14.0	37.8	$\boxed{27.5}$	0.6
Tjørndalen	4.0	21.3	38.9	$\boxed{14.4}$	0.2
Dyrstadflya	1.9	9.5	16.7	8.4	0.4
Lognedalsflya	2.2	5.1	18.7	$\boxed{32.6}$	0.2
Dunderdalen	2.1	12.9	33.3	1.5	0.6
Wijkanderberget	1.8	23.7	26.0	7.4	0.3
Bohlinryggen	1.5	53.0	19.9	$\boxed{36.8}$	0.5
Obervatoriefjellet	1.6	24.7	$\boxed{91.5}$	6.0	0.5
Tomtodden	2.9	31.7	40.5	$\boxed{37.2}$	0.6

4g. *Oncophorus wahlenbergii*

Place of collection	Cu	Mn	Zn	Pb	Cd
Calypsostranda	6.9	252.8	61.3	$\boxed{20.9}$	1.5
Lyellstranda	6.3	70.7	32.2	$\boxed{19.8}$	1.0
Tjørndalen	7.7	52.3	46.2	$\boxed{19.8}$	0.9
Lognedalsflya	4.1	202.7	28.3	$\boxed{17.1}$	0.8
Dunderdalen	6.6	116.0	56.3	$\boxed{12.9}$	$\boxed{1.3}$
Wijkanderberget	2.5	107.7	$\boxed{104.5}$	$\boxed{14.6}$	0.5
Bohlinryggen	2.8	123.2	50.0	$\boxed{13.1}$	0.7

4h. *Racomitrium lanuginosum*

Place of collection	Cu	Mn	Zn	Pb	Cd
Dyrstaddalen	○ 2.2	18.3	10.5	□ 11.1	0.3
Dunderdalen	○ 3.4	58.3	56.9	5.5	0.6
Tomtodden	○ 0.6	28.7	43.5	□ 15.7	0.5
Chamberlindalen	○ 2.5	17.4	68.3	□ 17.6	0.3
Wijkanderberget	○ 2.8	131.5	24.2	□ 13.7	□ 1.5
Obervatoriefjellet	○ 4.3	31.1	37.2	□ 43.2	0.4

○ metal concentration below its physiological level

□ metal concentration exceding its mean level described in literature

This deficiency was found in 24 species of the studied plants, which constitutes 40% of all plants analysed. In other plants Cu occurred at physiological concentrations (Tables 1, 2 and 3) of Cu content from 5–45 ppm in the soils of the studied area (Jóźwik and Magierski 1991, 1992, 1993).

Mn content

Manganese was found to occur in the concentration range from 9–900 ppm in plants as described in literature which was also observed by the author in all plants analysed.

Zn content

In literature the concentration of this metal in plants ranged from 15–80 ppm. However, increased Zn amounts exceeding physiological concentration were found by the author in many cases at its simultaneous low concentration in the soil (Jóźwik and Magierski 1991, 1992, 1993, 1995). Thus some plants can be supposed to accumulate this element. Increased Zn amounts were found largely in *Salix polaris,* one of the predominating plants in West Spitsbergen. The average Zn concentration in this plant was 160 ppm. This may imply a specific relationship to this metal. Regardless of the places of plant collection excess physiological amounts of Zn was found. Other vascular plants with excess Zn amounts were: *Salix reticulata* – 159.4 ppm, *Cerastium arcticum* – 97.4 ppm, bryophytes: *Bryum crithatum* – 157.0 ppm and *Pohlia polymorpha* – 101.0 ppm. All examined lichens showed Zn to occur at physiological concentrations.

Pb content

Besides Cd and Pb, As and Hg are considered to be strongly toxic elements which enter the human organism in food. However, only Pb is accumulated by people at concentrations approximate to the clinically toxic level. The danger of Pb presence results from the fact that its management is similar to that of calcium. Pb is a special threat to the natural environment, being injurious at any amount. Its average content in plants is assumed to be 0.9–9 ppm.

In the period of studies 1987–1995 higher than the average Pb amounts described in the literature (Kabata-Pendias and Pendias 1993) were found in many plants, largely bryophytes and lichens. In some of them Pb concentration was even two end three times higher than its average level. Bryophytes and lichens take up this metal from the air. The presence of Pb in these plants should thus be connected with anthropopressure in the given environment. Also in vascular plants increased Pb amounts were recorded, which may account for the uptake of this element through the root system and its accumulation in them (Jones *et al.* 1973).

Exceeded average Pb amounts were observed in such vascular plants as: *Cerastium arcticum* – 15.2 ppm, *C. officinalis* – 13.5 ppm, *Draba corymbosa* – 13.9 ppm, *Dryas octopetala* 12.4 ppm, *Luzula arctica* – 13.9 ppm, *Polygonum viviparum* – 10.6 ppm, *Salix polaris* – 10.4 ppm, *S. reticulata* – 16.1 ppm, *Saxifraga aizoides* – 20.6 ppm, *S. cernua* – 15.1 ppm, *S. oppositifolia* – 10.0 ppm and *Silene acaulis* – 11.5 ppm (Table 1); as regards bryophytes in 21 species of 25 examined, and in 11 lichens species of 13 analysed (Table 2 and 3). In general increased Pb amounts were found in 44 of 50 examined plant species, which constitutes 73%. Therefore, this metal can be considered as a threat to the natural environment of the investigated area.

Cd content

Although cadmium is easily taken up by plants, proportionally to its concentration in the soil, it is not needed for plant development. Most plant species are characterized by a high tolerance to this metal and do not show toxicity symptoms at its relatively high concentration. In soils Cd occurs in amounts from 0.15–0.2 ppm whereas in plants its concentration can reach 1.0 ppm, but when it is 4–13 ppm it is considered toxic for them (Kabata-Pendias and Pendias 1993).

In most studied plants the values of Cd content were average as described in literature. An exception was *Salix polaris,* a species which contained the highest Cd amounts (1.7 ppm on average) irrespectively of the places of collection. This plant is probably able to accumulate considerable amounts of this element. Its considerable amounts were also found in some lichens: *Cladonia gracilis* – 1.4 ppm, *Ochrolechia frigida* – 1.4 ppm, *Stereocaulon denudatum* – 3.2 ppm and *Xantoria elegans* – 1.7 ppm.

As it was noted in the introduction of this paper, the selection of plants for analysis of their content of heavy metals was conditioned by their predominating occurrence in various tundra stands. In most cases these plants live on littoral planes, mountain slopes and peaks and in valleys. They were plants of the genus: *Saxifraga, Salix, Dryas, Racomitrium, Oncophorus or Cetraria.* There were also other species which predominated in definite places of the area studied. They were also analysed for the content of trace elements with regard to a more complete analysis of the environment.

The data of Cu, Mn, Zn, Pb and Cd content for those plant species occuring in all places of collection or in most of them are presented (Table 4a–h).

To the plants occuring in all places of collection belong: *Saxifraga oppositifolia, Salix polaris* and *Silene acaulis*. In these tables the Cu concentrations below the physiological level described in literature are denoted by ellipses.

The content differentiation of the studied metals in the plants selected for analyses in various and, only in a few cases, depends on the places of collection. Attention is undoubtedly deserved by *Salix polaris* which, independently of these collection places, accumulates Zn exceeding its physiological concentration, and Cd exceeding its average level. Thus specific dependence for this plant can be taken into consideration.

In *Cetraria hiascens* and *Racomitrium lanuginosum*, however, Cu deficiency was shown regardless of the places of collection, which also refers to specific dependence. In recent years studies on the content of heavy metals in plants of West and South Spitsbergen were carried out among others by Drbal *et al.* (1992) and Grodzińska *et al.* (1993). The results obtained by these authors, particularly in the case of lichens, diverge in respect of some metals from those presented in this paper. It seems that this can be connected with geological, hydrological and pedological conditions as well as anthropopressure which is different for the described land areas. Many researchers paid attention to anthropopressure in their studies of the content of heavy metals (Jaworowski 1980, Heizenberg 1982).

Conclusions

On the basis of the obtained results from the studies of the content of Cu, Mn, Zn, Pb and Cd in tundra plants in the Bellsund region, West Spitsbergen, carried out in 1987–1995, the author found:

(1) Cu deficiency in many plant species,
(2) higher amounts of Zn exceeding its physiological concentration in some plant species, and higher than average amounts of Pb and Cd in plants,
(3) in all examined plants Mn concentrations within the physiological limits.

The fact of Pb accumulation by bryophytes and lichens as well as some vascular plants is alarming. Although plants form special resistance mechanisms against high concentrations of trace elements and are also characterized by a high tolerance to some metals, the increased Pb and Zn amounts which were demonstrated can be a threat to the natural environment.

References

DRBAL K., ELSTER J. and KOMAREK J. 1992. Heavy metals in water ice and biological material from Spitsbergen, Svalbard. — Pol. Res., 11: 99–101.

GRODZIŃSKA K., GODZIK B. and SZAREK G.1993. Heavy metals and sulphur in lichens from tundra Spitsbergen. — Fragm. Flor. Geob. Suppl., 2: 669–708.

HEINTZENBERG J. 1989. Arctic haze: Air pollution in polar regions. — Ambio 18: 50–55.

JAWOROWSKI Z. 1989. Pollution of the Norwegian Arctic. — Review Norsk Polarinst. Raportser., 55: 1–93.

JONES L.H., JARWIS S.C. and COWLING D.W. 1973. Lead uptake from soils by perennial ryegrass and its relation to the suply an essential element. — Plant Soil, 38: 605–619.

JÓŹWIK Z. 1990a. Heavy metals in tundra plants of the Bellsund Fiord area Spitsbergen. — Polish Pol. Res., 11: 401–409.

JÓŹWIK Z. 1990b. Heavy metals in tundra plants of the Bellsund region, Spitsbergen. II. Blomlidalen, Tjørndalen, Dyrstadflya and Lognedalsflya. — *In*: Wyprawy Geograficzne na Spitsbergen. — UMCS, Lublin: 159–165.

JÓŹWIK Z. 1991. Heavy metals in the tundra plants of the Bellsund Region, Spitsbergen. II. Chamberlindalen, Calypsostranda, Lyallstranda. — *In*: Wyprawy Geograficzne na Spitsbergen. — UMCS, Lublin: 163–170.

JÓŹWIK Z. and MAGIERSKI J. 1991. IV. Heavy metals in plants and soil of West Spitsbergen (Bellsund Region). — *In*: Wyprawy Geograficzne na Spitsbergen. — UMCS, Lublin: 171–177.

JÓŹWIK Z. and MAGIERSKI J. 1992. V. Trace elements in plants and soils of coastal plains of soth Bellsund (Western Spitsbergen). — *In*: Wyprawy Geograficzne na Spitsbergen. — UMCS, Lublin: 161–169.

JÓŹWIK Z. 1992. VI. Heavy metals in phylum Bryophyta in the Bellsund Region, Western Spitsbergen. — *In:* Wyprawy Geograficzne na Spitsbergen. UMCS, Lublin: 171–178.

JÓŹWIK Z. and MAGIERSKI J. 1993. VII. Contens of Cu, Mn, Zn, Pb and Cd in plant and soil on Western Spitsbergen-Bellsund Region. — *In*: XX Polar Symposium, Lublin: 181–197.

JÓŹWIK Z. and MAGIERSKI J. 1994. VIII. Heavy metals in the plants and soil of Calypsostranda in the Bellsund Region (West Spitsbergen). — *In*: Wyprawy Geograficzne na Spitsbergen. UMCS, Lublin: 179–189.

JÓŹWIK Z. and MAGIERSKI J. 1995. IX. Heavy metals in the plants and soil of Dunder valley (West Spitsbergen). — *In*: Wyprawy Geograficzne na Spitsbergen. UMCS, Lublin: 237–243.

JÓŹWIK Z. 1999. Heavy metals in tundra plants in the Bellsund region, Western Spitsbergen. — *In*: Antropologia Ekologiczna. — Wydawnictwo UMCS, Lublin: 69–75.

KABATA-PENDIAS A. and PENDIAS H. 1993. Biogeochemia pierwiastków śladowych. — PWN, Warszawa; 299 pp.

ŚWIĘS F. 1988. Zróżnicowanie geobotaniczne tundry na południowym wybrzeżu Bellsundu (Zachodni Spitsbergen). — *In*: Wyprawy Geograficzne na Spitsbergen. — UMCS, Lublin: 215–228.

Streszczenie

W latach 1987–1995, w ramach wypraw naukowych na Zachodni Spitsbergen, organizowanych przez Uniwersytet Marii Curie-Skłodowskiej w Lublinie, prowadzono badania nad zawartością metali ciężkich w roślinach tundry w rejonie Bellsundu. Badaniami objęto 22 gatunki roślin naczyniowych, 25 gatunków mszaków i 13 gatunków porostów. Wykazano u wielu gatunków zwiększone ilości Pb i Zn, co może stanowić o zagrożeniu naturalnego środowiska na badanym terenie tymi metalami. Z kolei u wielu roślin wykazano niedobór Cu. Mangan występował u wszystkich badanych roślin w granicach stężeń fizjologicznych.