Proc. Estonian Acad. Sci. Ecol., 1991, 1, N 2, 65—71
https://doi.org/10.3176/ecol.1991.2.02

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HEAVY METALS IN SNOW AND SOME INDICATOR PLANTS IN ESTONIA

Abstract. The content of heavy metals (Zn, Cd, Cu, Pb) in snow cover and four indicator plants (2 yr Scots pine needles; *Hypogymnia physodes*; *Cladina* spp., mainly *C. rangiferina*; *Pleurozium schreberii*) was studied. Some high contents were noted in Kurtna, north-eastern Estonia, near a large industrial centre. In general, the content of heavy metals in snow and plants was not higher in the industrial North Estonia than in South Estonia or on Vilsandi Island on the western coast. A considerable part of the heavy metal load comes from natural sources and distant regional sources. The level of heavy metal pollution in Estonia is similar to that in South Finland.

Key words: cadmium, copper, lead, zinc, snow, indicator plant, *Cladina* spp., *Hypogymnia physodes*, *Pinus sylvestris*, *Pleurozium schreberii*.

Introduction

The level of heavy metal pollution of the terrestrial environment in Estonia is mostly unknown. Only some papers have been published on this topic (e. g. Мартин, 1985).

The present study investigates the regional patterns in the occurrence of four heavy metals in precipitation and indicator plants in Estonia. The sampling points were chosen so that areas with high technogenic load as well as areas without greater local pollution sources were represented. In order to facilitate comparison, we selected such species of bioindicators, which have been used in analogous studies in North European countries and Poland.

Study Areas, Material, and Methods

To study the peculiarities of regional distribution of heavy metals in snow, sampling was carried out just before the melting of the permanent snow cover, i. e. in early March. Samples were taken at 32 points of the Estonian territory (Figs. 1—4) in 1985 and 1986. The sampling was performed with a plastic tube having a bottom area of 100 sq. cm. For each sample to be analyzed, five samples were mixed. The entire snow cover was penetrated during sampling. Samples were taken at a distance of at least 200 m from dwelling-houses.

The indicator plant samples (only green living biomass) were collected from 12 observation points during the summer of 1985 (late July) (Fig. 5). The number of sample replicates from Vilsandi Island, the westernmost part of Estonia, was 12—19. The observation points in North Estonia

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include sites near (15—20 km) industrial centres (Harku near Tallinn, Kurtna near Kohtla-Järve) and areas less influenced by human activities (Einby, Järvakandi, Viitna, Lohusuu). All species of bioindicators were collected from each observation point, however, some species (especially mosses and *Cladina*) were absent in some localities. The total number of samples of each species from North Estonian points was 3—5. In South Estonia five points (Põltsamaa, Tartu, Pärnu, Tipu, Lutepää) were studied: in total 6—8 samples of each species from these points were used for chemical analysis.

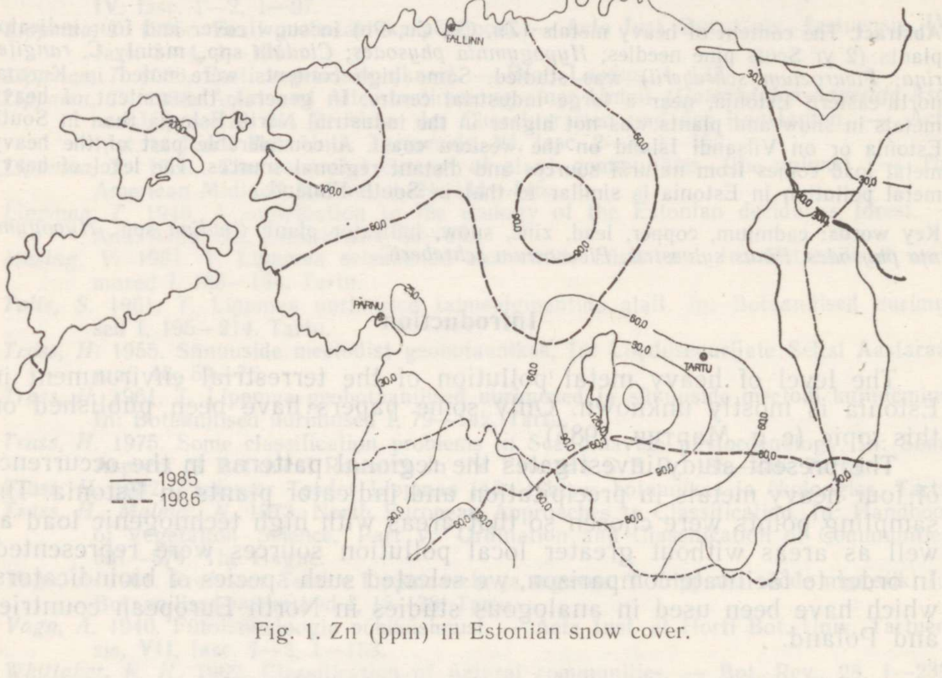

Fig. 1. Zn (ppm) in Estonian snow cover.

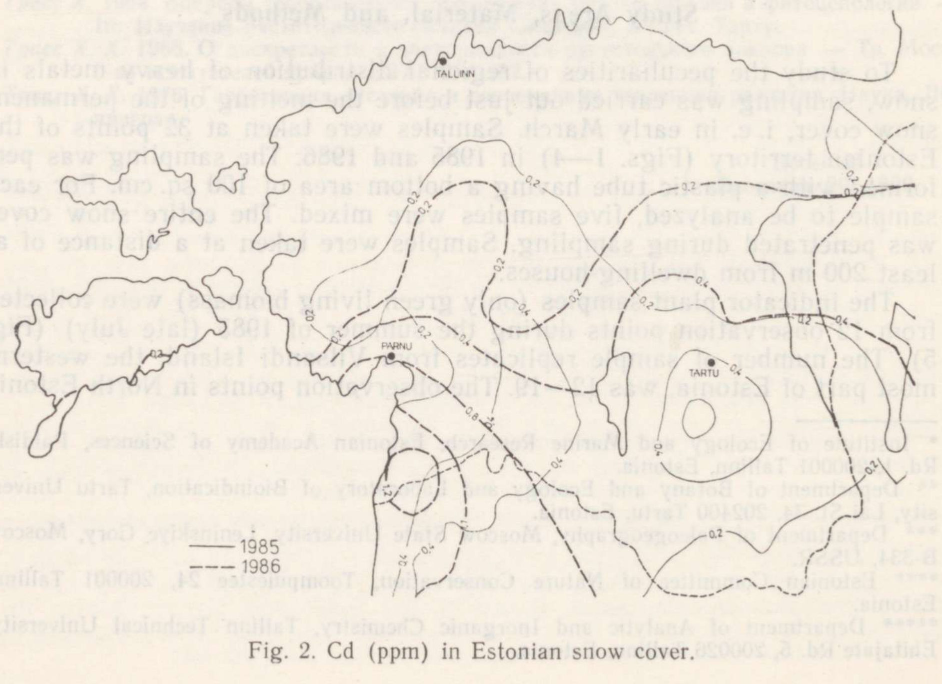

Fig. 2. Cd (ppm) in Estonian snow cover.

Four indicator plants were chosen: *Hypogymnia physodes*, *Pleurozium schreberii*, sometimes replaced by *Hylocomium splendens*, *Cladina* spp. (mainly *Cladina rangiferina*), and *Pinus sylvestris*. *Hypogymnia physodes* was collected from pine stems at breast height. From *Pinus sylvestris* only two-year old needles were analyzed.

Snow samples were melted at room temperature and then the sediment was digested by HNO_3. Plant samples were dried, homogenized, and digested by H_2O_2 and HNO_3. Both types of samples were analyzed for Zn, Cd, Cu, Pb by atomic absorption spectrophotometry; the results are given as ppm (=mg/kg=μg/g) of dry weight.

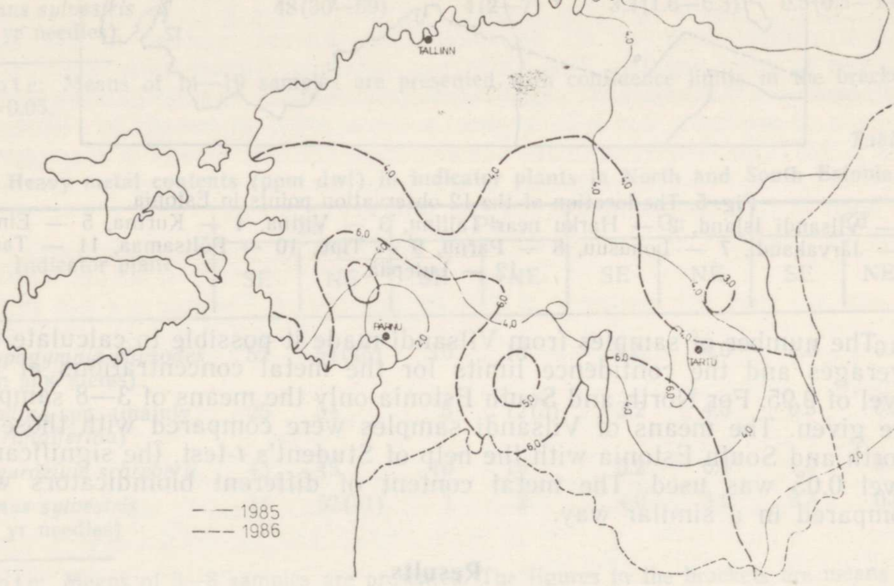

Fig. 3. Pb (ppm) in Estonian snow cover.

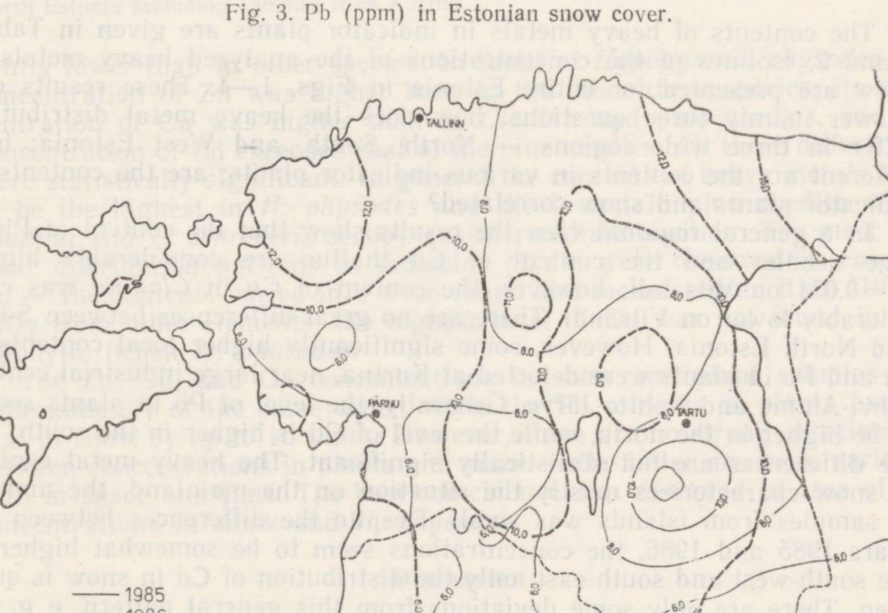

Fig. 4. Cu (ppm) in Estonian snow cover.

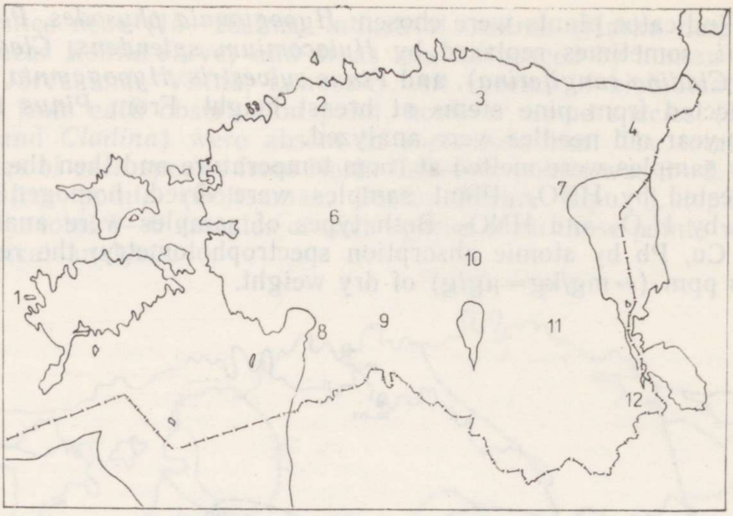

Fig. 5. The location of the 12 observation points in Estonia.
1 — Vilsandi Island, 2 — Harku near Tallinn, 3 — Viitna, 4 — Kurtna, 5 — Einby, 6 — Järvakandi, 7 — Lohusuu, 8 — Pärnu, 9 — Tipu, 10 — Põltsamaa, 11 — Tartu, 12 — Lutepää.

The number of samples from Vilsandi made it possible to calculate the averages and the confidence limits for the metal concentrations at the level of 0.95. For North and South Estonia only the means of 3—8 samples are given. The means of Vilsandi samples were compared with those of North and South Estonia with the help of Student's *t*-test, the significance level 0.05 was used. The metal content of different bioindicators was compared in a similar way.

Results

The contents of heavy metals in indicator plants are given in Tables 1 and 2, isolines of the concentrations of the analyzed heavy metals in snow are presented for entire Estonia in Figs. 1—4. These results can answer mainly three questions: how does the heavy metal distribution differ in three wide regions — North, South, and West Estonia; how different are the contents in various indicator plants; are the contents in indicator plants and snow correlated?

In a general regional view the results show that the content of Pb in pine needles and the content of Cd thallus are considerably higher ($p=0.05$) on Vilsandi; however, the content of Cu in *Cladina* was considerably lower on Vilsandi. There are no great differences between South and North Estonia. However, some significantly higher local contents of Zn and Pb in plants were detected at Kurtna, near large industrial centres Jõhvi-Ahtme and Kohtla-Järve. Generally, the level of Pb in plants seems to be higher in the north, while the level of Cd is higher in the south, but the differences are not statistically significant. The heavy metal content in snow characterizes mostly the situation on the mainland, the number of samples from islands was small. Despite the differences between the years 1985 and 1986, the concentrations seem to be somewhat higher in the south-west and south-east, only the distribution of Cd in snow is quite even. There are only some deviations from this general pattern, e. g. the contents of Pb and Cu were higher in the north-west in 1986.

Some specific peculiarities occurred in the accumulation of metals in different indicator plants. In pine needles the content of Pb was signifi-

Table 1

Heavy metal contents (ppm dwt) in indicator plants on Vilsandi Island, West Estonia

Species	Zn	Pb	Cu	Cd
Hypogymnia physodes (on pine stems)	76 (47—98)	15 (6—39)	5.9 (3.8—9.0)	1.0 (0.4—1.5)
Cladina (mainly *C. rangiferina*)	35 (24—59)	5 (4—7)	1.7 (1.2—2.3)	0.8 (0.6—1.2)
Pleurozium schreberii	39 (25—60)	7 (4—13)	0.5 (0.3—0.7)	0.5 (0.3—0.7)
Pinus sylvestris (2 yr needles)	48 (30—69)	4 (2—7)	3.3 (1.6—6.3)	0.5 (0.3—1.0)

Note: Means of 14—19 samples are presented with confidence limits in the brackets, $p=0.05$.

Table 2

Heavy metal contents (ppm dwt) in indicator plants in North and South Estonia

Indicator plant	Zn		Pb		Cu		Cd	
	SE	NE	SE	NE	SE	NE	SE	NE
Hypogymnia physodes (on pine stems)	52	54 (45)	15	18	4.2	4.0	1.3	0.8
Cladina spp. (mainly *C. rangiferina*)	25	34	5	12 (3)	3.2	4.5	0.3	0.2
Pleurozium schreberii	43	45	10	15	5.2	6.4	1.0	0.1
Pinus sylvestris (2 yr needles)	41	57 (41)	1	2	4.0	3.0	3.3	0.2

Note: Means of 3—8 samples are presented. The figures in the brackets are means for North Estonia excluding samples from Kurtna.

cantly lower than in other species. In thalli of *Hypogymnia physodes* the concentration of Zn was higher than in the other three species, its concentration of Cu was higher than in *Cladina* and pine needles, and its concentration of Cd exceeded that of the pine needles. All these differences were statistically significant. In general the contents of heavy metals tend to be the highest in *H. physodes* and the lowest in pine needles while *Cladina* and *P. schreberii* occupy an intermediate position. The most unclear distribution patterns in indicator plants were observed in case of Cu — the contents varied in a wide range and lacked regularities. Differently from other elements, the highest level of Cu was not found in the epiphytic lichen *H. physodes*.

The Zn, Cu, and Cd concentrations in snow and plant samples are approximately of the same order, while the Pb contents in plants exceed that in snow by up to 10 times. However, there are no strong correlations between concentrations in plants and snow — the latter are more variable both in space and time. The best coincidence was observed in case of Zn concentrations in snow and *H. physodes*.

Discussion

Comparing the three main regions of Estonia (South Estonia, North Estonia, and the western islands as represented by Vilsandi) one can see that the contents of Pb and Cd in indicator plants tend to be the highest on Vilsandi while the content of Cu in *Cladina* is lower there. No differences become evident in the comparison of North and South Estonia. The concentrations of Cd in indicator plants are higher in the southern part. As to other metals, the contents seem to be slightly higher in North Estonia. However, omitting some high values for Kurtna (Pb in *Cladina* spp., Zn in *H. physodes* and in pine needles), the pollution levels of the two regions are quite similar (Tables 1, 2).

An analysis of the results indicates a weak correlation between the metal contents in snow and indicator plants. For example, the highest contents of Pb in snow, pine, and *Cladina* spp. occurred in the nonindustrialized South. Cd in snow showed the highest values in South and West Estonia.

A comparison of different species shows that the highest heavy metal concentrations occur in *H. physodes*. The lowest content of Pb was detected in pine needles. The difference between *Hypogymnia* and moss was, however, statistically significant only for Zn. Some authors have reported a tendency towards higher accumulation in moss (cf. Burton, 1986 p. 23). Our results indicate likewise high concentrations in *Hypogymnia* which, thus, can serve better as an indicator species, as moss samples are hard to find in polluted industrial and urban areas.

If we compare the metal contents in Estonian plants with those reported in several regions of Europe and North America (Burton, 1986), we can see that the contents of Pb, Zn and Cd in Estonia are not high. The observed metal contents in Estonian *P. schreberii* and *H. physodes* are close to the lowest values of Europe and North America, in *Cladina* medium concentrations have been detected.

Some observations exist from the areas, where the metal contents are quite near the original background levels (Lodenius, Kumpulainen, 1983; Särkelä, Nuorteva, 1987; Gaugh et al., 1988). Our results show that the Estonian levels of Cd in *P. sylvestris*, *H. physodes*, and *P. schreberii* are generally higher than reported in these works, but for Zn the levels were lower for *H. physodes* and equal in pine needles. This kind of difference existed also when the metal levels between southern Finland and Lapland were compared (Särkelä, Nuorteva, 1987). In general, the comparison of our results to those reported from southern Finland also indicates similar levels (Laaksovirta, Olkkonen, 1977; Pakarinen et al., 1978; Lodenius, Kumpulainen, 1983; Nuorteva et al., 1986; Särkelä, Nuorteva 1987; Kanerva et al., 1988), but significantly lower than concentrations in some strongly polluted sites (cf. Rao et al., 1977; Burton 1986; Folkesson et al., 1988). The only exception is probably the higher content of Cd in Estonian *H. physodes*. The content is, on the contrary, lower than that measured in Poland (Grodzinska,1980; Särkelä, Nuorteva, 1987) and far below the critical level reported by Rao et al. (1977). In fact, the Estonian contents may be a little higher than those in southern Finland, as our samples were collected in July and the Finnish samples in August and the metal contents increase towards autumn (Koski et al., 1988; Nuorteva, 1988; Vilkka et al., 1990). The spatial distribution of industry on the territory of Estonia and the heavy metal isolines show that the majority of the studied elements reach the Estonian territory by way of long-distance transportation. The input is constant from the south-west and west, and less expressed from the south-east. The occurrence of *Carpinus* pollen among the pollen collected from the Pärnu study point also indicates the important role of the long-distance transportation from the south-west (Кофф, Пуннинг, 1985) — from the *Carpinus* areas in South Sweden and South Latvia. The contents of metals transported from these directions may vary with years depending on meteorological and atmospheric processes.

The influence of local pollution is more evident only in Kurtna, northeastern Estonia, near large industrial centres, where some higher concentrations (especially those of Zn and Pb) were measured.

The data obtained can be used in planning the systems of monitoring heavy metals transported over long distances as well as for metals liberated from soil by acid rain. Two observation stations would be enough for Estonia and they might be situated in the Pärnu Lowland and near the Otepää Heights. Investigations in industrial northeastern Estonia should be continued to characterize the role of local sources. To study short-term transportation processes atmospheric precipitation should be gathered and analyzed. *Hypogymnia physodes* would be most suitable for the investigation of integrated long-term changes in metal fallout. Because most metals originate from soil reserves, it is, however, also necessary to have an indicator plant with roots in the soil (e. g. *Vaccinium myrtillus*).

Acknowledgement. The authors thank Prof. P. Nuorteva for reading the first drafts of the manuscript and for many useful comments on it.

REFERENCES

Burton, M. A. 1986. Biological Monitoring of Environmental Contaminants (Plants.) — MARC Report 32. London.

Folkesson, L., Andersson-Bringmark, E. 1988. Impoverishment of vegetation in a coniferous forest polluted by copper and zinc. — Can. J. Bot., 66, 160—167.

Gaugh, L. P., Jackson, L. L., Sacklin, J. A. 1988. Determining baseline element composition of lichens. II. *Hypogymnia enteromorpha* and *Usnea* spp. at Redwood National Park, California. — Water Air Soil Pollution, 38, 169—180.

Grodzinska, K. 1980. Zanieczyszczenie polskich parkow narodowych metalami ciezkimi. — Zaklad Ochrony Przyrody Polsk. Akad. Nauk, 43, 9—27.

Kanerva, T., Sarin, O., Nuorteva, P. 1988. Aluminium, iron, zinc, cadmium and mercury in some indicator plants growing in south Finnish forest areas with different degrees of damage. — Acta Bot. Fenn., 25, 275—279.

Koski, E., Venölöinen, M., Nuorteva, P. 1988. The influence of forest type, topographic location and season on the levels of Al, Fe, Zn, Cd and Hg in some plants in Southern Finland. — Ann. Bot. Fenn., 25, 365—370.

Laaksovirta, K., Olkkonen, H. 1977. Epiphytic lichen vegetation and element contents of *Hypogymnia physodes* and pine needles examined as indicators of air pollution at Kokkola, W. Finland. — Ann. Bot. Fenn., 14, 112—130.

Lodenius, M., Kumpulainen, J. 1983. Cd, Fe and Zn content of the epiphytic lichen *Hypogymnia physodes* in a Finnish suburb. — Sci. Total Environm., 32, 81—85.

Nuorteva, P. 1988. Tutkimuksia metallien osuudesta metsiä tuhoavassa monistressisairaudessa. — Lounais-Hämeen Luonto, 75, 62—76.

Nuorteva, P., Autio, S., Lehtonen, J., Lepistö, A., Ojala, S., Seppänen, A., Tulisalo, E., Veide, P., Viipuri, J., Willamo, R. 1986. Levels of iron, aluminium, zinc, cadmium and mercury in plants growing in the surroundings of an acidified and a non-acidified lake in Espoo, Finland. — Ann. Bot. Fenn., 23, 333—340.

Pakarinen, P., Mäkinen, A., Rinne, R. J. K. 1978. Heavy metals in *Cladonia arbuscula* and *Cladonia mitis* in eastern Fennoscandia. — Ann. Bot. Fenn., 15, 281—286.

Rao, D. M., Robitaielle, G., LeBlanc, F. 1977. Influence of heavy metal pollution on lichens and bryophytes. — J. Hattori Bot. Lab., 42, 213—239.

Särkelä, M., Nuorteva, P. 1987. Levels of aluminium, iron, zinc, cadmium and mercury in some indicator plants growing in unpolluted Finnish Lapland. — Ann. Bot. Fenn., 24, 301—305.

Vilkka, L., Aula, J., Nuorteva, P. 1990. Comparison of levels of some metals in roots and needles of *Pinus sylvestris* in urban and rural environments at two times in the growing season. — Ann. Bot Fenn., 27, 53—57.

Кофф Т., Пуннинг Я.-М. 1985. О некоторых закономерностях воздушного переноса пыльцы. — Изв. АН ЭССР. Геол., 34, 3, 92—98.

Мартин Ю. 1985. Биогеохимическая индикация загрязнения среды при помощи спороных растений. — Изв. АН ЭССР. Биол., 34, 1, 1—15.

Received
January 7, 1991