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TECHNIQUES AND STRATEGIES

Bryobioindication of imission load in the Tatra Mountains, Slovakia

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Introduction

The idea of bryophyte utilization for bioindication arose in seventies (Clymo 1963, Rühling and Tyler 1970). This method is based on the fact, that majority of nutrients receive bryophytes from precipitation or from dry deposition. Bryophytes are more convenient for deposition survey than vascular plants because: (a) they are perennial plants without leafless period, (b) bryophytes have high cation exchange capacity without vital cell function damaging, (c) cuticle is absent. The high cation exchange capacity, lacking cuticle and simple thalli organisation make the bryophytes unable to avoid heavy metal accumulation from deposition (Tyler 1990). With respect to nutritional independence on substratum, the bryophytes are suitable indicators for deposition monitoring, in Europe and in the USA are broadly used for this purpose (Briggs 1972, Ratcliffe 1975, Groet 1976, Gydesen and Rasmussen 1981, Burton 1990, Maňkovská 1997, Maňkovská *et al.* 2003, 2008, and others).

The bryophytes exploitation as bioidicators is a simple method, in the present days is used for large areas monitoring, e. g. forest ecosystems (Maňkovská *et al.* 2003, 2008), industrial areas (Sumerling 1984, Zoltai 1988) or to reveal relation between altitude and deposition (Zechmeister 1994, Šoltés 1998).

Material and Methods

In a literature review, summarized Tyler (1990) knowledge on sensitivity or tolerance of 38 bryophyte species. Excessively senzitive appeared *Ptilium crista-castrensis, Dicranum polysetum, Rhytidiadelphus triquetrus, Aulacomnium palustre* and *Plagiomnium affine*.

The intensity of heavy metal accumulation is different in various bryophyte species (Burton 1990). In the term of high cation exchange capacity, the bryophytes are often recommended for heavy metal deposition monitoring (Clymo 1963, Ratcliffe 1975, Zechmeister 1994).

Large number of bryophyte species were used as bioindicators. The pleurocarpous moss species *Hypnum cupresssiforme* is often used as bioindicator (Gordon *et al.* 1971, Pilegaard *et al.* 1979, Sabovljević *et al.* 2005), as well as *Pleurozium schreberi, Hylocomium splendens* and *Dicranum* sp. (Maňkovská 1997, Maňkovská *et al.* 2008), exploitation of *Hylocomium splendens* as bioindicator is supported by Tamm (1953), Rühling and Tyler (1970), Tyler (1990) and by others as well. *Pleurozium schreberi* appeared as senzitive species for lead presence (Tyler 1990). The liverwords were used for biomonitoring as well. The thallose plant *Marchantia polymorpha* showed high resistance against air pollutants (Briggs 1972, Grözinger 1974). Some hydrophytes were used as bioindicators, e.g. *Rhynchostegium riparioides, Cinclidotus danubicus, Fontinalis antipyretica* (Burton 1990), also *Scapania undulata* (Tyler 1990) and *Hygrohypnum duriusculum* (Šoltés 1992).

Vukojević *et al.* (2005) investigated heavy metal accumulation from coal ash by bryophytes. *Bryum capillare* and *Ceratodon purpureus* appeared tolerant against high concentration of Fe, Mn, Zn, Pb, Ni, Cd, Cu.

The Tatra Mts as an object of bryobioindication

Even though the idea of bryobioindication erose in the late sixties or in the beginning of seventies, regularly were used far later, particularly in the nineties, in accordance with the accessibility of the atomic absorption spektrophotometry methods. Although in foreign countries, notably in Europe and in the USA this method is broadly used, from Slovakia, distinctively from the Tatra Mts. are only moderate data disposable.

Šoltés (1992) evaluated results of chemical analysis of 267 samples of 26 bryophyte species collected on the territory of the High Tatra Mts - *Dicranum scoparium, Andreaea nivalis, Aulacomnium palustre, Bazzania trilobata, Sanionia uncinata, Hygrohypnum duriusculum, Hylocomium splendens, Leucobryum glaucum, Plagiomnium affine, Mnium spinosum, Paraleucobryum longifolium, Pleurozium schreberi, Polytrichum commune, Polytrichum formosum, Polytrichum juniperinum, Polytrichum strictum, Ptilidium pulcherrimum, Ptilium crista-castrensis, Rhytidiadelphus triquetrus, Sphagnum centrale, Sphagnum compactum, Sphagnum girgensohnii, Sphagnum capillifolium, Sphagnum quinquefarium, Sphagnum fallax, Sphagnum robustum.* The following metals were determined in the moss tissues: Pb, Cd, Cu, Zn, Cr, Fe, Mn and Mo. The following important trends were revealed: Disproportion between increasing Cr concentration and the other elements, increasing Cr and Mn concentrations in tissues of *Plagiomnium affine, Mnium spinosum, Hygrohypnum duriusculum, Sphagnum centrale* and *Sphagnum fallax*, increasing Pb concentration in relation to the altitude. *Hygrohypnum* *duriusculum* has appeared as a convenient moss species for Cr, Cd and Mn monitoring, *Plagiomnium affine, Mnium spinosum, Sphagnum centrale* and *Sphagnum fallax* for Cd and Mn monitoring, *Paraleucobryum longifolium* for Pb and Cd monitoring, *Andreaea nivalis* and *Sphagnum robustum* for Pb monitoring, *Polytrichum commune* and *Polytrichum formosum* for Mo and Mn monitoring.

Šoltés *et al.* (1992) explored imission influence to non-forest vegetation of the High Tatra Mts. and the Belanian Tatra Mts. Their investigation was focused to the proportion of heavy metals in deposition compared with proportion of heavy metals in the tissue of the moss species *Polytrichum commune*. Determined metals were Pb, Cd, Cu, Zn, Cr, Fe, Mn, Mo.

They worked in six transects: Zadné Meňodoly, Dolina Siedmich prameňov, Skalnatá dolina, Velická dolina, Furkotská dolina, Grúnik. In every transect were selected three sites. The proportion of heavy metals in deposition compared with proportion of heavy metals in the tissue of the moss species *Polytrichum commune* surprisingly punctually document a high sensitivity of this moss and its suitability for bioindication.

In 1995 a large area of three north facing valleys of High Tatra Mts. was attacked by spruce bark beetle. Šoltés (1996) analysed relation of insect outbreak to heavy metal deposition, 112 bryophyte samples were collected in attacked area and in adjacent not attacked area. The following bryophytes species were used as bioindicators: *Bazzania trilobata, Ptilidium pulcherrimum, Andreaea nivalis, Aulacomnium palustre, Dicranum scoparium, Hygrohypnum duriusculum, Hylocomium splendens, Leucobryum glaucum, Mnium spinosum, Paraleucobryum longifolium, Plagiomnium affine, Pleurozium schreberi, Polytrichum formosum, Polytrichum commune, Polytrichum juniperinum, Polytrichum strictum, Ptilium crista-castrensis, Rhytidiadelphus triquetrus, Sanionia uncinata, Sphagnum capillifolium, Sphagnum centrale, Sphagnum compactum, Sphagnum fallax, Sphagnum girgensohnii, Sphagnum quinquefarium, Sphagnum robustum.* The folloving metals were determined: Pb, Cd, Cu, Zn, Cr, Fe, Mn, Mo. The following trends have been revealed: (a) disproportion between increasing concentration of Cr and the other elements, (b) increase of Mo in the tissues of moss species collected on the southern slopes, (c) increase in Cd and Cr concentrations in the samples collected inside the insect outbreak area.

78 permanent plots in the grid of 16 x 16 km in the territory of Slovakia established Maňkovská (1997), the plot in the Tatra Mts. is not punctually specified. In the moss species *Pleurozium schreberi, Hylocomium splendens* and *Dicranum scoparium* are determined Cd, Cr, Cu, Fe, Hg, Ni, Pb, V and Zn. The identified concentrations are compared to the situation in 1991/1995 (The data source in 91/95 not reported). The Cu, Fe and Ni content recorded increase, the Cd, Pb and Zn content recorded decrease compared to 1991/1995.

The peat moss *Sphagnum girgensohnii* used Šoltés (1998) for bioindication of imission load of Tatra Mts. with special focus to correlation between altitude and heavy metal deposition. The peat moss occurs in forest ecosystem and in alpine level as well. In forest ecosystem, the peat moss was collected in clearings, at least 5 m from the immediate tree. The samples were collected in vertical interval 50 – 150m from 700m a.s.l. to the alpine level (2,000m a.s.l.) in 1986-1989. With respect to the particular picking conditions, the samples couldn´ t be collected in transect. The following elements were determined: Pb, Cd, Zn, Fe, Cu, Cr, Mn, Mo and S. With altitude are correlated Pb, Cd and Zn, these elements are related to traffic. Cu, Cr, Mn, Mo, Fe and S have their origin ore by mining and processing and their presence may be attributed to the long-distant transfer. Statistically significant correlation of heavy metal concentration and altitude shows only lead ($p = 0.01$).

Maňkovská *et al.* (2003) collected 831 samples of *Pleurozium schreberi, Scleropodium purum, Hypnum cupressiforme, Hylocomium splendens, Polytrichum formosum* and *Dicranum scoparium*, determined were elements: Cd, Cr, Cu, Fe, Ni, Pb and Zn. The most important producers of imission and fly ash are coal power plants, chemical industry, leaded petrol, ore processing. This method allowed to identify the areas affected by industrial imissions. Increased heavy metal concentration in the east part of the country is noticeable. The Tatra localities are unidentifiably.

Atmospheric deposition in the Carpathians using bryophytes examined Maňkovská *et al.* (2008). In the moss species *Pleurozium schreberi, Hylocomium splendens* and *Dicranum* sp. is determined broad spectrum of elements, chiefly metals: Ag, Al, As, Au, Ba, Br, Br, Ca, Ce, Cl, Co, Cr, Cs, Cu, Fe, Hf, Hg, I, In, K, La, Mg, Mn, Mo, Na, Ni, Pb, Rb, Sc, Se, Sm, Sr, Ta, Tb, Th, Ti, V, W, Yb, Zn, Zr. Directly in the territory of the Tatra Mts is not placed any site, the mountain range Kozie chrbty near Východná is the most immediate site to the Tatra Mts. The recorded concentrations are compared with the values in the North Norway. An example is Hg concentration in settlement Východná 11 x higher, Cu 7,8 x higher, Pb 23,1 x higher, Cr 28,8 x higher than in the North Norway.

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References

Briggs, D. 1972: Population differentiation in *Marchantia polymorpha* in varions lead pollution levels. *Nature*, **238**: 166-167.

Burton, M.G.S. 1990: Terrestrial and aquatic bryophytes as monitors of environmental contaminants in urban and industrial habitats. *Botanical journal of the Linnean Society*, **104**: 267-280.

Clymo, R. 1963: Ion exchange in *Sphagnum* and its relation to bog ecology. *Annales Bot. N. S.* **27**: 309-324.

Gordon, T., Goodman, T. and Roberts, M. 1971: Plants and Soils as Indicators of Metals in the Air. *Nature*, **231**: 287-292.

Groet, S.S. 1976: Regional and Local varations in heavy metal concentrations of bryophytes in the northeasterns United States. *Oikos*, **27**: 445-456.

Grözinger, O. 1974: Untersuchungen zur Kennzeichnung von Gassschäden an *Marchantia polymorpha* mit Hilfe von Leitfähigkeits- und Gasstoffwechselmessungen. Dissertation Arbeit. Tübingen.

Gydesen, H. and Rasmussen, I. 1981: Differences in the regional deposition of cadmium, copper, lead and zinc in Denmark as reflected in bulk precipitation, epiphytic cryptogams and animal. *Ambio*, **10**: 229-230.

Maňkovská, B. 1997: Deposition of heavy metals in Slovakia – assessment on the basis of moss and humus analyses. *Ekológia*, **16**: 433-442.

Maňkovská, B., Florek, M., Frontasyeva, M.V., Ermakova, E., Oprea, K. and Pavlov, S.S. 2003: Atmospheric deposition of heavy metals in Slovakia studied by the moss biomonitoring technique, neutron activation and lame atomic absorption spectrometry. *Ecologia*, **22**(**1**): 157-162.

Maňkovská, B., Oszlányi, J. and Barančok, P. 2008: Measurement of the atmosphere loading of the Slovak Carpathians using bryophyte technique. *Ekológia*, **27**(**4**): 339-350.

Pilegaard, K., Rasmussen, L. and Gydesen, H. 1979: Atmospheric background deposition of heavy metals in Denmark monitored by epiphytic cryptogams. *Journal of Applied Ecology*, **16**: 843-853.

Ratcliffe, J. M. 1975: An evaluation of the use of biological indicators in an atmosphaeric lead survey. *Atmospheric Environment*, **9**: 623-629.

Rühling, Å. and Tyler, G. 1970: Sorption and retention of heavy metals in the wooland moss *Hylocomium splendens* (Hedw) Br. Et Sch., *Oikos*, **21**: 92-97.

Sabovljević, M., Vukojević, V., Michajlović N., Dražić G. and Vučinić Z. 2005: Determination of heavy metal deposition in the county of Obrenovac (Serbia) using mosses as bioindicators. I: Aluminium (Al), arsenic (As), and boron (B). *Arch. Biol. Sci.*, **57**(**3**): 205-212.

Sumerling, T.J. 1984: The use of mosses as indicators of airborne radionuclides near a major nuclear installation. *Science of the Total Environment,* **35**: 251-265.

Šoltés, R. 1992: Heavy metal concentrations in the mosses of the Tatra Mountains (Czecho-Slovakia): Multivariate analysis. *Oecologia Montana*, **1**: 31-36.

Šoltés, R. 1996: Insect outbreak in relation to heavy metal deposition in the moss species. *Oecologia Montana,* **5**: 93-96.

Šoltés, R. 1998: Correlation between altitude and heavy metal deposition in the Tatra Mts (Slovakia). *Biologia*, **53**(**1**): 85-90.

Šoltés R., Šoltésová A. and Kyselová Z. 1992: Vplyv imisií na nelesnú vegetáciu Vysokých a Belianskych Tatier. *Zborník prác o Tatranskom národnom parku*, **32**: 307-333.

Tamm, C.O. 1953: Growth yield and nutrition in carpets of a forest moss (*Hylocomium splendens*). *Meddelanden fran statens Skogsforskninginstitut*, **43**: 1-140.

Tyler, G. 1990: Bryophytes and heavy metals, a literature review. *Botanical Journal of the Linnean Society*, **104**: 231-253.

Vukojević, V., Sabovljević, M. and Jovanović S. 2005: Mosses accumulate heavy metals from the substrata of coal ash. *Arch. Biol. Sci.* **57**(**2**): 101-106.

Zechmeister, G.H. 1994: Correlation between altitude and heavy metal deposition in the Alps. *Environmental Pollution*, **89**: 73-80.

Zoltai, S.C. 1988: Distribution of base metals in peat near a smelter at Flin Flon, Manitobe. *Water, Air and Soil Pollution*, **37**: 217-228.