Bioaccumulation of radiocesium by lichen *Hypogymnia physodes*

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Abstract: Cesium ^{137}Cs bioaccumulation experiments were carried out at 20 °C using natural samples of the foliose epiphytic lichen *Hypogymnia physodes* with wet weight/air dried weight ratio 2.33 ± 0.19 (SD). Thalli collected from oak bark were incubated in water CsCl solutions spiked with $^{137}CsCl$ for up to 24 h. Exposure to 2.5 μmol/dm^3 CsCl led to rapid ^{137}Cs uptake, typical for sorption processes, followed by slow time dependent bioaccumulation process, typical for biochemically catalyzed processes and transport across biological membranes. Uptake of 100% was reached within 6–24 hours. Pretreatment of thalli for 15 min in water at 60 °C caused fully inhibition of the slow-time dependent phase of bioaccumulation, not the initial rapid phase. Bivalent cations Ca^{2+}, Ba^{2+} and Mg^{2+} at 1 mmol/dm^3 did not influence radiocesium uptake, Cu^{2+} and Sr^{2+} ions at 1 mmol/dm^3 caused 90% and 40% decrease in radiocesium uptake, respectively. In the presence of Na^+ ions at 1 mmol/dm^3 radiocesium uptake was not influenced, concentration 160 mmol/dm^3 (0.9% NaCl) caused the four-fold decrease in the radiocesium uptake. Monovalent cations Li^+, K^+ and NH_4^+ at 1 mmol/dm^3 caused 50, 65 and 85% decrease in radiocesium uptake, respectively. Obtained results show that bioaccumulation of cesium by lichens will be suppressed by salinity of water and soils, the fact that can influence data quantifying ^{137}Cs contamination obtained by lichens as probes in biomonitoring studies. The same negative effect can be expected in monitoring studies, where lichens were exposed to temperature stress causing inactivation of ion transport or to low temperatures in boreal landscapes causing decrease of metabolic activity.

Key words: radiocesium, $^{137}Cs^+$, bioaccumulation, lichen, *Hypogymnia physodes.*

Introduction

Radionuclides in the environment originate from nuclear weapons testing and nuclear accidents. Soil contaminated with radiocesium ^{137}Cs and ^{90}Sr represents a long-lasting health hazard mainly via food-chain transport routes (Fesenko & Lissiansky, 1997; Entry & Watrud, 1998; Kovacova & Sturdik, 2002). Aspects of strategies to develop plants for phytoremediation of contaminated land and for production of crop to minimize the entry of radiocesium directly into the human food-chain were reviewed by White et al. (2003). Approximately 90% of radiocesium in lichens of European countries originated from the Chernobyl nuclear accident (Strandberg, 1994).

Lichens are symbiotic organisms composed of fungi (the most frequently *Ascomycetes*, rarely *Basidiomycetes*) and photosynthetic organisms (cyanobacteria or green algae) (Lisci et al., 2003). Lichen-dominated vegetation covers approximately 8% of Earth's land surface (Nash, 1996; Haas et al., 1998; Černohorský, 2000). Therefore, from the global point of view, lichens play an important role in plant ecology and in geobiochemical carbon, nitrogen and phosphorus cycles. Lichens are not equipped with root systems and with any impermeable cuticular surface limiting free cation uptake (see, e.g., Nash, 1996 and references cited therein). The whole surface of the lichen biomass can absorb nutrients as well as a broad spectrum of pollutants, such as heavy metals (Richardson, 1995). They can thus serve as indicators of toxic substances in the biosphere (Sloof, 1995; Garty, 2001).

Many papers and extensive studies describing utilization of lichens in monitoring of uranium effluents (Fahselt et al., 1995; Haas et al., 1998; Purvis et al., 2004) and radionuclides from nuclear weapons testing or nuclear reactor accidents (Sloof & Wolterbeek, 1992; Steinnes & Njastad, 1993; Godoy et al., 1998; Heinrich et al., 1999; Nedič et al., 1999, 2000; Kirchner & Daillant, 2002; Adamo et al., 2004) have been published. The most detailed experimental data were obtained in transport studies for K^+, Na^+, Mg^+, NH_4^+ ions, as well as for other essential elements and for Fe^{2+}, Mn^{2+}, Co^{2+}, Zn^{2+}, Cd^{2+}, and Cu^{2+} ions (Avery, 1996; Maegher, 2000). The above-mentioned reports showed that Cs^+ transport is

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