DESCRIPTION FOR THE GENERAL PUBLIC

Adaptations of lichens to heavy metal pollution, i.e. the key to their success in colonising extremely contaminated areas

Lichens constitute a symbiotic association composed of a lichen-forming fungus (mycobiont) and eukaryotic alga and/or prokaryotic cyanobacterium (photobiont). These organisms have acquired a number of specific features, of which the most important are distinct morphology and anatomy and unique metabolic pathways. Lichens have no root system or protective cuticle layer; therefore, they absorb all elements through the entire surface of the body. The specific structure and physiology of lichens decide their success in the colonisation of environments extremely hostile to life; they are pioneer organisms in both natural and anthropogenic habitats.

The abundance of some lichen species in areas affected by high levels of heavy-metal contamination indicates their great capacity for adaptation to the toxicity of the substrate. Bioaccumulation, defensive, and detoxification mechanisms developed in lichens are among the more interesting aspects of modern lichenology. Lichens sensitive or tolerant to contamination demonstrate different bioaccumulation patterns. Some species avoid excessive loads of elements, while others show a clear tendency towards hyperaccumulation, although this does not limit their growth. Various mechanisms are also potentially responsible for the removal or disposal of excess metal in the thalli. The morphological and anatomical plasticity of thalli, the selection of photosynthetic partners more resistant to contamination, chelation of metals by secondary metabolites, and the production of oxalates are often considered properties which facilitate lichen colonisation of contaminated habitats.

Despite many studies, knowledge about the biology of lichens occurring on extremely contaminated substrates, their adaptation strategies, and physiological responses to heavy-metal stress is still insufficient; previously published results are often inconclusive and sometimes even contradictory. Our previous studies conducted on post-smelting slag dumps have shown that some lichens are key pioneers capable of colonising extremely contaminated substrates, where concentrations of heavy metals such as lead and zinc far exceed acceptable levels even for post-industrial wastes. The fruticose lichen *Cladonia rei* appears to be the most effective lichen and often constitutes the main biomass in the initial stages of succession. It is often accompanied by *C. cariosa* and the crustose lichen *Diploschistes muscorum*, known as a hyperaccumulator of metals. These three species clearly dominate within a specific cryptogamic community which we have identified as typical of disturbed habitats in Europe. Thus their occurrence at such sites must be associated with exceptional adaptability rather than with the phenomenon of coincidental presence.

The fundamental questions we would still like to see answered are: why do certain lichens successfully colonise highly contaminated habitats? How does the lichen thallus as a whole functional entity cope with the enormous content of heavy metals in the host substrate? What are the compensatory mechanisms?

We intend to specifically investigate this problem in relation to the three aforementioned model species. The project has an interdisciplinary character, since it involves the examination of lichen responses to heavy-metal contamination at various levels of structure and functioning: morphology, anatomy, secondary metabolite production, physiology, photobiont identity. Moreover, the project represents a comprehensive approach to the problem, and many aspects will be considered simultaneously. Most studies of this topic examine the impact of particular heavy metals on lichen functioning parameters within laboratory experiments. The present undertaking is aimed at the identification of the cumulative effect of several elements (As, Cd, Cu, Pb, Zn) on lichens occurring naturally in polluted environments. The project design enables exploration of the problem over a full spectrum of substrate contamination and eliminates, to the extent possible, the influence of other external factors. A wide range of research methods will enable us to conduct a detailed analysis of the morphological and anatomical modifications of lichen thalli, to determine the bioaccumulation capacity of each species along with an indication of the total and intracellular metal fraction of the elements, to determine secondary metabolite content, to identify photobionts, to analyse photosynthetic pigment content and photosynthetic efficiency, and to determine oxidative stress and defensive strategies. Various statistical analyses of the obtained data will enable identification of significant relationships between lichen functional parameters and the content of elements in the thalli and substrate.

We believe that our results will contribute a great deal of new information to current knowledge on how the plasticity of various parameters of lichens contributes to the heavy-metal resistance of the model lichen species. This will help to explain their success in the colonisation of strongly contaminated sites. Learning about the functioning of these pioneer organisms is the first step towards conscious and complex planning of reclamation treatments including the consideration of lichens as an important element.