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Study of Potentially Toxic Elements Uptake into Organs of *Quercus* spp. from Copper Deposits in Slovakia, Italy and Portugal

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Abstract

The article is focused on the application of Energy dispersive micro X-ray fluorescence spectroscopy as a specific method to determine the contents of potentially toxic elements and its spread in plant tissues. As a model species, *Quercus* spp. were selected. In order to compare the obtained results with previous research, four well-described abandoned Cu-deposits were selected for sampling: Ľubietová (Slovakia), Libiola and Caporciano (Italy), and São Domingos (Portugal). The results of micro X-ray fluorescence spectrometry confirm the irregular contamination of *Quercus* spp. by potentially toxic elements. The level of contamination is the highest predominantly in the root cortex, where is also the highest Ca contents (with exception of São Domingos). At Ľubietová and Caporciano, high Ni content was described in branches cortex, in branches mesoderm also Fe, Cu and Zn. At the same time, the inhibition influence of Ca was also confirmed regarding the input of these elements into plants.

Keywords Micro X-ray Fluorescence Spectrometry · Contamination · Plant organs · Plant tissues · Ca-inhibition influence

In the plant's life cycle, a continuous metal transport occurs by extraction of various elements from environmental water solutions. The input of these metals is realized mostly by root extremities. Potentially toxic elements (PTE), including radioactive isotopes are usually controlled by binding with various compounds, which decrease their toxicity and enable their transport in order to accumulate in vacuoles predominantly of parenchymatic tissues (Frey et al. 2000; Küpper et al. 1999; Marques et al. 2004; Shaheen et al. 2007; Mwegoha 2008) and binding to cell walls (Bringezu et al. 1999; Memon and Schröder 2009). Parenchyma cells with a large central vacuole may occur as aggregates forming parenchyma tissue in the cortex and pith of stems and roots, the mesophyll of leaves and in the conducting tissues as xylem and phloem parenchyma (Crang et al. 2018). These mechanisms provide removal of surplus metals from the cytosol to avoid interference with metabolic processes (Banásová et al. 2012). The PTE are immobilized in organs such as dermal tissue, bark, trichomes and thorns what results in less harm of plants health (Vaculík 2018). These procedures are critical in stress areas with significant metal content like mining scenarios.

Bioavailability of soil elements, including metals, is predominantly shaped by soil reaction (pH/Eh), presence of organic material, mineralogy, land use, as well as by plant root exudates and other complexes of plant species additionally. In order to determine the process of bioavailability, the investigated elements should be present in soil in potentially bioavailable forms—mobile/exchangeable, bound to organic matter, bound to Fe, Mn and Al amorphic oxides, and bound to acid soluble compounds (Midula et al. 2017b; Wiche et al. 2017). It is attributed to substances exuded from plant roots, known to contain small amounts of organic acids (both carboxylic and amino) (Nigam et al. 2001).

The primary aim of this article is to specify the accumulation character of selected PTE in the root, branch and leaf

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