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Sequential extraction based environmental risk assessment of potentially toxic elements in the topsoil of two sloping vineyards (Tokaj-Hegyalja, Hungary)

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Soils in vineyards face various agronomic problems, such as low organic carbon content, fertility loss, and soil erosion. In particular, the intensive use of fertilizers and copper-based fungicides has resulted in the enrichment of potentially toxic elements (PTEs) in vineyard soils. These PTEs are recovered in different geochemical fractions, significantly affecting their behavior and toxicity in the soil environment. Therefore, in the present study, the geochemical distribution of Zn, Pb, Co, Ni, Cr, and Cu in the topsoil of two sloping vineyards in Tokaj-Hegyalj (NE Hungary) was investigated using the BCR sequential chemical extraction method. A risk assessment code (RAC) was also used to explore the environmental risk related to the labile fraction of the PTEs.

The two sites display contrasted soils: a slightly acidic soil derived from a magmatic rock (rhyolite) in a more than 100-year-old conventional vineyard near Tállya and a moderately alkaline soil developed on loess in a 28-year-old organic vineyard near Tokaj. Our results indicate that the target PTEs are considered immobile due to their high contents recovered in the residual fraction in both vineyards. However, Co, Cu, and Pb show the highest affinity for the reducible fraction (bound to iron and manganese oxyhydroxides). Therefore, those elements are more labile and can easily be released into the soil solution upon changes in the redox potential. Indeed, reducing conditions lead to the decomposition of the oxides or hydroxides. Conversely, the oxidizable PTE fractions are below 10%, indicating their weak binding to soil organic compounds. The soil pH, $CaCO_3$ content, and silt content play a significant role in the geochemical fractionation of PTEs in the soil. The calculated RAC based on the percentage of PTEs in the acid-soluble soil fraction reveals that Pb and Cr have a safe risk level (RAC less than 1%), while a low risk is indicated for Zn and Ni (RAC < 10%) in both vineyards. Medium (RAC < 30%) and low risk are associated with the acid-soluble Cu in Tállya and Tokaj, respectively. The increased environmental risk due to the continuous use of copper-based fungicides and the subsequent accumulation of Cu in vineyard soils should be monitored, especially in old vineyards.