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The remediation of abandoned mine tailing dumps using a pioneer plant species *Pinus halepensis* Mill.

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The reclamation of highly degraded abandoned mine tailings subjected to the pollutants dispersion in the surrounding areas is a crucial socio-economic issue. The use of plant species locally adapted with complementary ecological functions of the contaminated site and well-adjusted to the low soil functions without interfering with the local biodiversity is considered as a recovery technique.

The pioneer plant species *Pinus halepensis*, is growing spontaneously in Sardinian mine tailing dumps (SW- Sardinia, Italy) characterized by extreme concentrations of pollutants, mainly Zn, Pb, and Cd. In this study, a sampling campaign was done, related to plant materials (roots, barks, wood, and needles) and soils, aimed at assessing metal content, plant accumulation, and translocation behavior as well as the main mineralogical characteristics of the soil-plant system in a multidisciplinary approach.

Mineralogical compositions of substrates and roots assessed through X□Ray Diffraction (XRD) detected mainly pyrite, dolomite, calcite, quartz, gypsum, and barite in the polluted substrates with the presence of iron sulphate, iron oxide as well as Zn, Pb, Cd, and other elements (Al, Si, and Fe) in different amounts on the plant root surface. Zn ore minerals (smithsonite) and muscovite were mostly in the deeper soil horizon. Zn was the most abundant metal in the substrate as well as all investigated plant tissues. The highest metals concentration range in the soil samples collected around the plant roots were measured for Zn (9043.2 -15299.52 mg kg^{-1}), Pb (1604.47 – 4413.29 mg kg^{-1}), and Cd (46.11 -58.54 mg kg^{-1}). *P. halepensis* roots accumulated high metal concentrations (664.65 - 2710 mg kg^{-1} Zn, 58.39 - 735.88 mg kg^{-1} Pb, and 4.86 - 11.02 mg kg^{-1} Cd) mirroring the high metal-contamination in soil and plant's ability to tolerate highly metal polluted mine sites.

The Phyto-stabilization potential of the plant was calculated through the biological accumulation and translocation parameters reported below one for all investigated plant tissues. Metal Translocation Factor (TF) detected in needles for Pb, Zn and Cd ranged between 0.03-0.32, 0.03-0.19, and 0.04-0.14, respectively and Cd TF (0.05-0.2) was more in wood than needles (0.04-0.14). Biological Concentration Factor (BCF) values of Cd, Zn and Pb were estimated to be 0.11-0.19, 0.07-0.18 and 0.02- 0.17, respectively.

The low metal TF rates indicated that the pioneer woody plant species *P. halepensis* behaves as an excluder. Thus, we can consider it as a promising plant that tolerates high concentration of Zn, Pb, and Cd and restrict the accumulation and translocation of metals to the aerial parts, performing his role as a woody plant species for long term reclamation, Phyto-stabilization, and re-vegetation process in abandoned mine tailing sites of arid and semiarid Mediterranean regions.