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# Integrated system for rehabilitation of mine wastes and exploitation of added-value compounds from Cistus ladanifer

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The rehabilitation of mining areas with sulfide materials, both abandoned and active mines, is a priority because these areas are sources of acid mine drainage and multielemental contamination and, consequently, environmental and health risk. The combined use of Technosols and Phytostabilisation accelerates the area recovery, and ensures the sustainability at long-term of the physical, chemical and biological processes involved in the rehabilitation due to the functional complementarity of the components. Nowadays the rehabilitation strategy of contaminated areas must be based on circular economy, environmental improvements and economic approaches.
Cistus ladanifer L. is an autochthones and spontaneous species that contributes to natural rehabilitation of contaminated soils from mining areas. Moreover, bioextracts obtained from C. ladanifer growing in São Domingos mining area (Iberian Pyrite Belt) presented several valuable compounds, which can provide an economic return by their use for fragrance and pharmaceutical approaches. This study aimed to evaluate, under controlled conditions, the efficiency of an integrated system for the rehabilitation of sulfide-rich and gossan tailings, which combines the application of Technosols and Phytostabilisation, and exploitation of added-value compounds from C. ladanifer bioextracts.
The rehabilitation system comprised a surface layer of Technosol and a barrier of alkaline residues (biomass ashes and limestone wastes) that covered sulfide-rich wastes. Two Tecnosols composed of gossan wastes and different mixtures of agro-industrial wastes (from distilleries and greenhouse agriculture without any valorisation) at 150 Mg/ha were tested. In the Technosols was seeded C. ladanifer. After three years of plant growth, shoots biomass was quantified and used to obtain bioextracts (extraction with n-hexane). The organic composition of the bioextracts was determined and some compounds with added value ($\alpha$-pinene, camphene, camphor, fenchona and verbenone) were quantified.
During the assay, the Technosols presented better structure, pH (5,7–6,0) and concentrations of organic C (9,0–26,2 g/kg) and NPK (204–490 mg Ntotal/kg, 163–329 mg Pextractable/kg, 80–308 mg Kextractable/kg), compared to control (only gossan wastes; pH: 3.7–4.0; [Corg]: 2.2–5.2 g / kg; Ntotal]: 126-341 mg / kg; [Pext]: 0.2–0.9 mg/kg; [Kext]: $\approx$ 20 mg/kg). In Technosols, concentrations of nutrients (Ca, Fe, K, Mg, Mn and Zn) in available fraction (Rhizzo extraction) were also higher (>50-fold compared to control) but Cu and Pb concentrations decrease.
The improvement of these characteristics in the Technosols stimulated the germination (control: 1 %; Technosols: 5–11 %) and plant growth. After 40 days, seedlings from control died but the Technosols support the vegetative growth at long-term. The shoots biomass obtained was between 67.9 and 76.4 g of fresh weight, corresponding to 5.8 and 6.7 ton of dry weight/ha.
The increase of evapotranspiration by C. ladanifer growth and the alkalinizing barrier decreased the sulfide oxidation of the sulfide-rich wastes and, consequently, the generation of acid drainage and dispersion of potentially hazardous elements by leachates.
Several compounds with economic interest were quantified, being benzenepropanoic acid the major compound (15–42 %). Verbenone showed significant concentrations in bioextracts ($\approx$7 mg/kg). The integrated rehabilitation system was adequate and sustainable, contributing to the recovery of unproductive and contaminated areas, which can be economically exploited.