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Improvement of chemical and biological characteristics of gossan mine wastes following application of amendments and growth of Cistus ladanifer L.

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Cistus ladanifer is considered a good option for phytostabilization of mine wastes, composed of several materials, but its growth is very slow due to substrata conditions (acidic pH, low fertility and water availability, high total concentrations of hazardous elements). To enhance the growth of *C. ladanifer* with application of organic/inorganic amendments can be a strategy to speed up remediation. This study aimed to evaluate the influence of different rates of amendments and *C. ladanifer* growth on the improvement of chemical and biological characteristics of *gossan* wastes. Composite samples of mining wastes (*gossan*+host rocks) were collected at the São Domingos mine. Amendments used were mixtures (30, 75, 150 Mg/ha) of rockwool, agriculture wastes and wastes from liquor distillation obtained from fruits of *Arbutus unedo*. Four treatments (n=6 replicates) were carried out (control and three amended treatments) under controlled conditions in a greenhouse. After one month of incubation at 70% of water holding capacity, *C. ladanifer* was sown in half of the pots from each treatment (n=3), and the other three pots remained in the same conditions without plant. Chemical and biological characteristics of the wastes (with/without plants) were analysed after incubation and fifteen months.

Gossan wastes had great total concentrations of several elements (g/kg; Al: 24.8, As: 3.03, Cu: 0.23, Pb; 9.21) whereas in an extracting solution (diluted solution of organic acids) these were small ($<$5.7% of total). The amendments improved the pH ($>$0.5 units), fertility ($C_{organic}$, $P_{extractable}$, N_{total}) and dehydrogenase activity of mine wastes, principally with the rate of 150 Mg/ha, even after one month of incubation and after the plants be sown. In both sampling periods (beginning/end of the experiment), $K_{extractable}$ concentrations increased only with the high application rates (control and 30 Mg/ha treatment: 1.02–1.88 mg/kg; other amended treatments: 2.13–3.55 mg/kg).

At the end of the experiment, the presence of the plant increased $C_{organic}$ and $P_{extractable}$ concentrations, compared to treatments without plants, reaching the highest values in the treatments combining amendments and plants. After one month of incubation, the dehydrogenase activities in wastes were more than twice in the amended treatments (1.71–33.55 μg TPF g sample $16h^{-1}$, depending on amendments application rate and sampling period). Nevertheless, wastes from treatments with plants had higher dehydrogenase activities (9.66–33.55 μg TPF g sample $16h^{-1}$, depending on amendments application rate) than in treatments using only amendments (4.98–22.30 μg TPF g sample $16h^{-1}$), but both were higher than control. The plants in control presented lower fresh biomass than in amended treatments. Plants growth in control was not sufficient to enhance dehydrogenase activity of mine wastes (1.51 and 1.72 μg TPF g sample $16h^{-1}$, with/without plants, respectively).

The extractable nutrients (Ca, Fe, K, Mg, Mn, Zn) increased with amendment application, an advantage for remediation purposes. Although extractable Al, As, Na also increased in the same treatments, they remained small. In contrast, extractable Cu and Pb were, generally, lower in amended treatments than in control. The presence of the plant did not increase the concentration of elemental in the extractant solution.