Selection of amendments to decrease the mobility and toxicity of inorganic pollutants (Pb, As, Ba, Zn) in a mine tailing for the development of a phytoremediation process

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1. Introduction

In mining sites, the alteration of tailings induces a risk of dispersion of potentially toxic elements inducinga potential pollution of groundwater and surface water. The development of a vegetal cover is one of the potential options to decrease the risks through mechanical and biogeochemical stabilization of pollutants and attenuation of run-off/on and erosion. However, the growth of plants on mine tailings and associated technosols is generally hampered by several parameters: acidity, lack of nutrients, poor texture and toxicity of metals and metalloids. Thus, amendments are necessary to overcome these limitations prior to vegetalisation. A range of amendments, organic and inorganic, were proposed to improve the phytostabilisation processes (Alkorta et al., 2011). Here, several amendments were tested for the stabilization of Pb, As, Ba and Zn in tailings from a Pb-Ag former mine. The effects of these treatments on microbial metabolic diversity and on the early growth of ryegrass were evaluated.

2. Materials and methods

Tailings were sampled on the former silver and lead mining site of Pontgibaud located in medium mountain, Auvergne, France (Sabourault et al., 2016). Mine residues were recovered from the 0-60 cm depth level of a mine waste dump, in seven discrete zones in a 25 m^2 area, using a power shovel. The tailing is acidic (4<pH<5), siliceous and coarse (76% of particles with size in the range of 315 µm – 2 mm). Total concentrations in pollutants were as follow: 26 432 $mg.kg^{-1}$ Pb, 265 $mg.kg^{-1}$ Zn, 1 063 $mg.kg^{-1}$ Ba, 1134 $mg.kg^{-1}$ As. Previous studies showed that, in absence of amendment, it is not a good substrate for plant growth (Norini et al., 2019).

The selected amendments were cow manure and ochre (iron oxide-hydroxide) material produced in the water treatment plant of a coal mine. First of all, they were tested in the laboratory in pot experiments single or in combination, in 10% solids leaching tests, at 5% (weight of dry amendment/weight of tailing). Subsequently, microcosms experiments were performed in 200 mL polystyrene pots, whose bottom was perforated to allow water flow, filled with tailing, amended or not. The different tested conditions were the following: tailing without amendment (T), tailing + 5% ochre (TO), tailing + 5% ochre + 0.15% manure (TOM 0.15%), tailing + 5% ochre + 1% manure (TOM 1%), tailing + 5% ochre + 2% manure (TOM 2%).The microcosms were watered once a week and the percolating water was analyzed to quantify pollutants. The effects of amendments on metabolic microbial activities were evaluated using Ecolog® plates. Soils recovered in microcosm pots after 1 month of incubation were used to test the growth of ryegrass in 200 mL polystyrene pots, 50 mm diameter, whose bottom was perforated to allow water flow. Pots were incubated in a Phytotron with 60 % air water saturation, 16 h of light (white fluorescent light 500-600 $µm.m^{-2}.s^{-1}$) at 25°C alternately with 8 h of darkness at 18 °C.

3. Results and discussion

3.1. Immobilization of metal(loid)s

Leaching experiments showed that the best combination of amendments to immobilize Pb while avoiding significant mobilization of As, Zn and Ba was a mixture of ochre and manure at 5% of each amendment. Ochre can contribute to the treatment by increasing pH and by adsorbing As and metals. Manure is necessary to supply nutrients for plant growth. The efficiency of immobilization of pollutants was confirmed during microcosm experiments: Pb concentration, that was higher than 10 $mg.L^{-1}$ with the not-amended tailing, was decreased by a factor ×100, while As, Zn and Ba concentration did not increase significantly.

3.2. Effects of amendments on microbial activity and plants

The average color development (AWCD) in Ecolog® plates is an expression of the microbial activity in the sample and integrates the cell density and the diversity of substrate utilization (Figure 1). Amendments with ochre and manure increased and modified the metabolic activity. Metabolic activities per family of substrates expressed by the AWCD appeared to be higher when amendments were added to the tailing. This activity was the strongest for TOM 2%. Polymers with the highest percentage of utilization are the most used substrates, suggesting the presence of a specialized microbial community. There was a shift in the substrate utilization intensity. Ryegrass created a less favorable environment for certain microbial groups in the soil: With ryegrass, the microbial community preferred to use simpler substrates and no longer seems to be able to use complex substrates like polymers. At the end of the incubation with ryegrass, the most active microbial communities were found for TOM 1%.

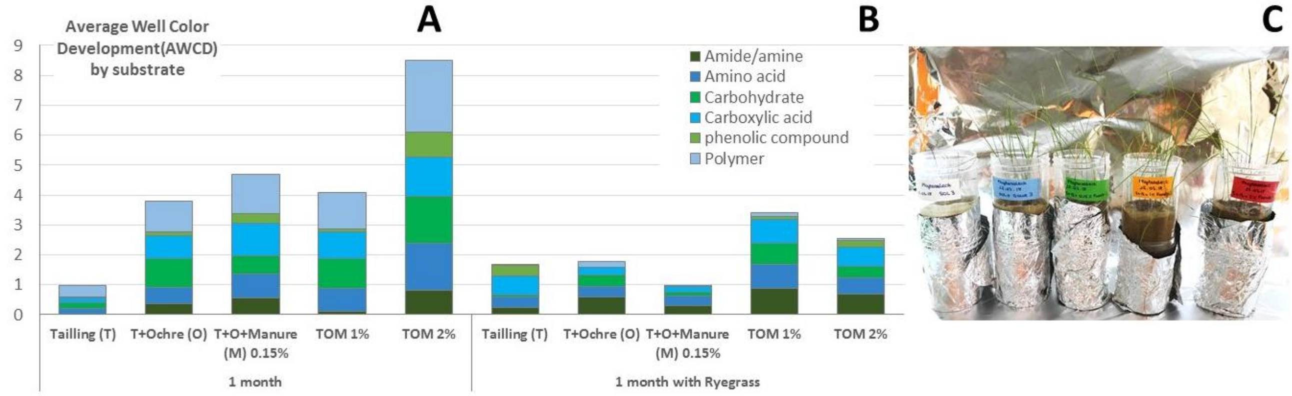

Figure 1.Soil microbial activities of the microcosms after 1 month of incubation without (A) and with (B) ryegrass, and picture of the planted microcosms (C).

The germination rate of ray grass varied with the amendment: 83 % for T, 100 % for TO, 97 % for TOM 0.15%, 94 % for TOM 1%, and 78 % for TOM 2%. The growth of plants was significantly improved by the addition of ochre and manure (Figure 1C): the biomass of ryegrass is 3.5 X (TOM 2%) to 4.8 X (TOM 0.15%) times greater than for the condition of plants growing on unamended soil (data not shown).

4. Conclusions

The combination of ochre (5%) and manure (0.15% to 2%) is efficient to stabilize Pb in the tailing, without mobilizing other pollutants, i.e. As, Zn and Ba at the microcosm scale. Both amendments improved the microbial activity of the tailing and stimulated the development of ryegrass. The next experimental step will include the monitoring of phytostabilization and ecodynamics of contaminants at metric scale, in mesocosm, with a vegetal species naturally present on Pontgibaud mine site, belonging to the *Agrostis* genus.

5. References

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