**Assessment and characteristics of heavy metal polluted soils developed in waste heaps from an old serpentinite quarry**

Andres Rodriguez-Seijo, Daniel Arenas-Lago, Manoel Lago-Vila, Flora A. Vega, Luisa Andrade

Department Plant Biology and Soil Science. University of Vigo. As Lagoas. Marcosende. 36310. Vigo. Spain andresrodriguezseijo@uvigo.es

Abstract

Quarrying activities in areas with serpentinized rocks may have a negative impact on plant growth. In Galicia (NW Spain), there are substantial areas of serpentine, the most noteworthy being the Cape Ortegal ultramafic complex.

A serpentinite quarry was selected in this zone (Moeche, A Coruña, NW Spain), it is an old quarry (56 hectares) of metamorphic origin, namely Penas Albas (PA). This exploitation was active from 1960 to 1999, with a 50000 Mg Year-1 production of ornamental stone called "Green Pyrenees". As a result of this activity, the spoils are formed with lots of sterile waste and have caused a significant impact on the environment.

Four soils were selected: three in the quarry spoils, with different slopes and spoil abundance (PA1, PA2 and PA3), and another in the cutting zone (PA4). Furthermore, a control soil was sampled outside the exploitation area (PAC) and located in a *Pinus pinaster* Ait. reforestation zone. The factors that limit plant growth, especially the heavy metal content and their distribution in soil geochemical phases, were determined, as well as it was evaluated the quality of the soils.

The results show that in soils developed in the abandoned quarry, the limitations for plant growth were: moderate alkaline pH (7.87-8.05), strong Ca/Mg (<1) imbalance, low N (<0.42 mg kg-1) and P (<2 mg kg-1) contents, and high total heavy metal content (Co 76-147 mg kg-1; Cr 1,366-2,605 mg kg-1; and Ni 1,342-2,039 mg kg-1). In all cases these levels exceed the maximum limit permitted in soils. After chemical sequential extraction it was found that the high content of Co, Cr, and Ni, is associated with the residual fraction of the soils. In addition, Fe and Mn oxides have a high capacity for Co fixation, whereas Cr and Ni are mainly associated with magnesium silicates. The fractions associated to organic matter and the soluble or available forms are, respectively low and very low, not exceeding 2.5% in any of the soils. This association of the metals with magnesium silicates and Fe oxides, and the low content of metals bound to organic matter were identified by using the TOF-SIMS and SEM-EDS techniques. Both techniques confirmed and verified the results obtained with the chemical sequential extraction by checking the interaction of heavy metals with the different soils components.

The use of the Soil Quality Index (SQI), allowed verifying the low quality of the soils, mainly in the areas of waste disposal (26.32-47.37%).

Restoration work should be geared towards introducing a stable mixed vegetation cover, including serpentinophile species, which would provide the necessary modifications to correct nutritive imbalances and improve soil quality.

Acknowledgements

This study was financed by the Xunta de Galicia, under project EM2013/018. F.A. Vega thanks the Ministry of Science and Innovation, and the University of Vigo for the Ramón y Cajal contract. D. Arenas-Lago was also awarded with an FPI-MICINN pre-doctoral fellowship (BES-2011-044311). A. Rodríguez-Seijo thanks the University of Vigo for his pre-doctoral fellowship