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Ecological engineering tools to remediate and restore trace metal and metalloid polluted sites in Mediterranean protected areas

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The Mediterranean basin is one of the world hot-spot of biodiversity. However past and current activities impacted and still affect its biodiversity and its functionality. One of the major issues is the trace metal and metalloid (TMM) contamination of Mediterranean soils in a context of soil rarefaction. A multidisciplinary approach gathering experts in ecology, environmental chemistry, microbiology and environmental law was adopted to develop ecological engineering tools to remediate and restore heavy metal polluted sites in Mediterranean protected areas.

With the background of ecological restoration that initiates or speeds up the return of an ecosystem to its historic trajectory, we aimed at bringing knowledge for the reestablishment of a dynamic enabling polluted ecosystems to recover levels of functionality that will give them new strength and resilience or, at least, stopping their process of degradation.

We first propose tools for a non-destructive and integrative approach to analyze TMM soil contamination and to select metal-tolerant native plant species. Secondly, we developed ecological tools for the management of polluted soils *in situ*, in such way that the respect of their biological quality and their biodiversity are the main objectives taken into account. Moreover recovering these biological traits is a premise in a holistic ecological action plan. We aimed at limiting the risk of pollutant release and transfer from the soil to other environmental compartments, and therefore lower human population exposure to pollutants. Thus, following with microbial functional diversity in soils as essential factor for the *in situ* environmental management of polluted sites, the phytostabilization process, amongst the various phytoremediation processes, has as target at stabilizing the contaminants at soil level and / or at the rhizosphere. Thereby, the process of phytostabilization seems to be the treatment the most compatible with ecological restoration.

Based on the outcome of a case-study in the National Park of Calanques (south-east of France) conducted in situ through a long-term pilot assay (six months) that focused on functional traits of native plant species and root symbioses involved in TMM tolerance and, with the help of the Calanques agricultural high school, we initiated a production chain for non-commercial plant species and adapted agro-ecological practices favoring the recovery of plant growth in our field, whose results led us to validate our methodology. Further, this in-situ approach could be extrapolated to other TMM polluted sites in Mediterranean climate areas, and on a larger scale be implemented in the law.

Keywords: ecological restoration, pseudometallophytes, functional traits, root symbioses

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