Biologically-assisted treatment of soils both contaminated with Heavy Metals and Polycyclic Aromatic Hydrocarbons.

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This research plan proposes the study and development of enhanced phytoremediation technologies as an environmental remediation method to treat contaminated soils with heavy metals (HMs) and polycyclic aromatic hydrocarbons (PAHs). Biodegradable compounds are proposed as amendments to improve the phytoremediation efficiency in an environmentally friendly approach.

Phytoremediation is an emerging remediation technology that can be defined as the use of plants to remove pollutants from the environment or to make them harmless (Interstate Technology and Regulatory Cooperation (ITRC) Work Group, 2001). Phytoextraction and rhizodegradation are two types of phytoremediation technologies that can be both used together to clean-up contaminated soils (Pivetz, 2001). In phytoextraction, plants have a central role as HMs are taken up by plant roots and translocated to the above ground tissues. In contrast, in rhizodegradation plants have a secondary role in the dissipation of organic contaminants. Plants release root exudates that promote microbial growth and activity in the rhizosphere, which leads to the biodegradation of organic compounds such as PAHs. A key factor limiting the efficiency of phytoremediation is the bioavailability of contaminants i.e. the ability of a pollutant to be transferred from a soil compartment to a living organism. For this reason, several compounds have been studied as amendments that increase the bioavailability of contaminants (Evangelou et al., 2007). However, many of them are synthetic and not biodegradable substances which tend to persist long in the environment increasing the leaching risk and can even be toxic for plants and microorganisms. In alternative, biodegradable compounds such as low molecular weight organic acids (LMWOAs) and surfactants have also been proposed. LMWOAs are strong ligands that can hold trace elements in solution by forming soluble complexes with HMs, which may even be taken up by plant roots. LMWOAs are naturally present in the soil rhizosphere as they are produced by plants and microorganisms and, unlike synthetic chelates, they are easily biodegradable and less phytotoxic (Jones, 1998). Furthermore, LMWOAs may also have a role in the remediation of organic contaminants such as PAHs. Surfactants are surface-active substances with amphiphilic chemical structure, which can increase the water solubility, and consequently the bioavailability of hydrophobic compounds (Gao et al., 2007). Besides, surfactants also have a part in removing HMs from soil surfaces, probably through the formation of complexes, micelles and ion exchange processes. Biosurfactants, i.e. surfactants produced by microorganisms are more biodegradable and less toxic, making these compounds a better choice for surfactant-enhanced bioremediation (Mulligan, 2005).

The main general objective of this project is to study the effect of LMWOAs and surfactants on the phytoremediation of soils co-contaminated with HMs and PAHs. Specific objectives include: (1) studying the effects of LMWOAs and surfactants on the HM and PAH bioavailability, (2) analyzing and comparing the phytoremediation efficiency of LMWOAs and surfactants, and (3) proposing a combined treatment with

LMWOAs and surfactants suitable for the phytoremediation of co-contaminated soils. Zinc and pyrene are chosen as representative HM and PAH contaminants that are known to be present in multipolluted soils (Ouvrard et al., 2011). Alfalfa (*Medicago sativa*) will be the candidate plant as it is fast growing and has an extensive root system, both characteristics desired for phytoremediation species. Besides, alfalfa has been shown to be tolerant of HMs and PAHs and has been used to remove these contaminants from the soils (Peralta-Videa et al., 2002; Fan et al., 2008). Citric acid and Tween-80® will respectively be the main LMWOA and surfactant under study.

Research activities will involve laboratory, growth chamber and greenhouse studies using the following methodologies. The bioavailability of contaminants will be studied by *in situ* soil solution extraction studies. The rate of HM phytoextraction will be assessed by the determination of plant biomass, quantification of HMs in plant parts and soils and calculation of phytoextraction parameters. The study of PAH rhizodegradation will be achieved by the quantification of PAHs in soil, calculation of PAHs removal rate and measurement of soil microbial biomass and activity.

Through this research work it is expected to achieve new insights in the emerging environmental phytotechnologies contributing to the development of more effective applications of phytoremediation technologies to treat soils contaminated with HMs and PAHs.

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