Ex Situ Biological Treatment of Hydrocarbon Contaminated Soil with eCUBE Microbial Electrochemical Technology

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Background/Objectives. Landfarming (biopile) technology is among the most used ex situ biological treatment methods for the removal of hydrocarbons and other biodegradable contaminants from soils and sediments. In this application, the soil is placed in heaps in which humidity and optimal oxygenation are maintained. Depending on the ways in which these two parameters are controlled, the biopiles can be called "static" or "dynamic". In the static biopiles, an aeration system provides the oxygen necessary to carry out the biodegradative processes. The limits of this type of technology are in the possible formation of preferential paths to the insufflation of air and in the non-homogeneous distribution of fluids within the heaps. These limitations can result in a non-optimized treatment in the whole volume of the material. In the dynamic biopiles, the homogenization of the material, oxygenation and the correct degree of humidity are guaranteed by periodic turning. In this type of approach, the optimal homogeneity and oxygen distribution are obtained. However, this technology has a higher cost than static biopiles and a less efficient use of the plant area due to a lower value of the ratio between the volume of treated material and the plant area. Microbial electrochemical technologies (METs) might help in overcoming the aforementioned limitations of the current soil biological treatments. These technologies are based on the ability of certain bacteria to use electrodes as final terminal electron acceptor during anaerobic respiration. Coupling electrode respiration and contaminant biodegradation allows to stimulate the biological decontamination processes by providing an inexhaustible source of terminal electron acceptors without the need of soil turning. The aim of this work was to develop, at laboratory scale, a biological soil treatment based on bioelectrochemical technologies.

Approach/Activities. The eCUBE technology (patent pending) is based on the use of graphite electrodes buried in the contaminated soil which act as anodes and cathodes. Oxidation reactions occur at the anodic surface, whereas reduction ones occur at the cathode surface.

eCUBE can operate either as a microbial fuel cell (MFC), when spontaneous redox reactions generate electricity or as a microbial electrolysis cell, when a small energy input (0.2 to 1 V) forces thermodynamically unfavored reactions or enhances spontaneous ones. To increase the radius of influence of the electrodes, the soil is provided with electron shuttle amendments such as biochar, sulfate and humic acids.

Results/Lessons Learned. The eCUBE technology in MEC configuration was demonstrated at laboratory scale for the remediation of a hydrocarbon contaminated soil using different electrode distances and amendments. The results showed that the contaminants were efficiently removed in all MET systems with up to 88% removal. The rate of hydrocarbon removal in the METs resulted higher than in the open circuit control. In the best tested condition the biodegradation rates were similar to those obtained in the traditional aerobic landfarming treatment. The overall structure of the microbial community did not show a significant difference between treatments in the soils. However, the enrichment of some hydrocarbon degrading and electroactive bacteria was observed in the METs, both in the bulk soil and on the anodes, compared with the aerated and open-circuit controls.