Enhanced Bioremediation of Pentachlorophenol-Contaminated Soil

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Background/Objectives. Pentachlorophenol (PCP) is an acutely toxic chlorinated aromatic biocide that has been used as a wood preservative since 1936. It was so widely used that worldwide annual production was estimated at 50,000 tons in the early 1980s. In 2022, the U.S. EPA issued a final registration review decision that requires US production of PCP to end as of 2024 and its use to be discontinued by 2027. The decision was based on health risks and environmental impacts associated with PCP use and the availability of viable alternative wood preservatives. Its wide use over the past 85 years resulted in contamination of soil at many industrial sites, and more than 300 US NPL sites are known to have soil or groundwater contaminated with PCP. The high acute microbial toxicity of PCP, and the fact that it is commonly deposited to soil with petroleum hydrocarbons and PAHs from creosote has made bioremediation of these soils challenging.

Approach/Activities. Bench-scale testing was conducted to compare the ability of various soil treatments including inorganic nutrients, organic amendments, pH adjustment, inoculation with a PCP-degrading bacterial culture, and imposition of anaerobic conditions to increase biodegradation of PCP. The influence of soil treatments on PCP biodegradation in soil from a wood preserving site was evaluated through a radioisotope mass balance study that monitored the conversion of added ^{14}C-PCP to ^{14}C-CO_2. Reductions in soil PCP concentrations were determined by standard solvent extraction and gas chromatography. Following completion of bench-scale testing the most effective soil amendments were applied to full-scale treatment of soil contaminated with PCP at several wood preserving sites in Canada and both wood preserving and industrial chemical production sites in the US.

Results/Lessons Learned. Detailed results from bench-scale testing on two industrial soils will be presented and discussed from the perspectives of PCP chemistry, acute toxicity, and soil microbial ecology. The results suggest that for heavily contaminated soils biodegradation of PCP can be stimulated more effectively with organic amendments than with inorganic nutrients. Results from the ^{14}C-PCP mass balance study indicated that the reduction in soil PCP concentrations during treatment is mainly due to complete biodegradation of PCP to carbon dioxide. An important finding is that soil amendments which increase soil water holding capacity without promoting creation of anaerobic conditions can be used to increase the rate and extent of PCP biodegradation. Conversely, soil amendments that result in anoxic conditions can sharply reduce biodegradation of PCP. The results from two completed full-scale projects, including initial and final PCP concentrations, treatment times, and cost factors, will be presented and discussed. During full-scale treatment using the organic amendment approach, soils with initial PCP concentrations as high as 3,500 mg/kg were successfully treated with attainment of the applicable remedial goals. As an example, treatment for a period of 127 days reduced soil PCP by more than 99% from an initial concentration of 2,890 mg/kg to 11 mg/kg.