Institution: **Carnegie Mellon University**

Project title: **Effects of Sediment Biogeochemistry on the Environmental Fate and Persistence of Polychlorinated Biphenyls (PCBs)**

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Project Summary

Polychlorinated biphenyls (PCBs), 209 compounds formerly manufactured and used in liquid mixtures as insulation in electric equipment, are toxic pollutants that persist in the environment. PCBs have contaminated a number of major rivers and coastal waters of the U.S. They adsorb on particles and deposit in sediment, which then acts as a reservoir for long-term release of PCBs to surface water ecosystems. PCBs accumulate in fish, move through the food chain, and as probable human carcinogens, pose a risk to people. The objective of our research was to improve understanding of the coupled physical, chemical, and biological processes that govern the degradation of PCBs in and release from river sediments.

Key Developments and Findings

- Experiments with PCB-contaminated sediments under anoxic conditions have demonstrated that the type and amount of nutrients and organic acids in contaminated river sediments, i.e., the particular geochemical conditions, affect significantly the biotransformations and therefore the fate of PCBs in river sediments. The effects of nutrients and simple organic carbon sources vary with particular sediments: different results were achieved with sediments from two different PCB-contaminated rivers.
- A key objective was to identify micoorganisms responsible for PCB biodegradation in contaminated river sediments. A method for the DNA identification of PCB-dechlorinating organisms in contaminated river sediment has been developed. The method includes an important enrichment step based on the addition of a specific PCB congener (BZ-29) to river sediment which increases the populations of PCB-dechlorinating microorganisms. Profiles of amplified 16S rDNA fragments from PCB-contaminated sediments from two rivers show significant differences in the microbial communities. Profiles of amplified 16S r DNA

fragments from the anaerobic PCB-spiked enrichment samples show changes in microbial communities as conditions change and PCB-degrading organisms are selectively enriched.

- Known microbial dechlorinators of PCE and other chlorinated compounds were identified in Grasse River and Hudson River samples by successful PCR amplification of their 16S rDNA fragments. PCB dechlorinators may share physiological and genetic properties with these known dechlorinators.
- Cloning libraries of 16S rDNA PCR amplified fragments (amplicons) have been established for selected groups of organisms, including methanogens and known (non-PCB) dechlorinators. DGGE profiles and DNA sequencing of these libraries have shed light on (1) the level of complexity of microbial communities in PCB-contaminated sediments, (2) the composition of the microbial communities in these sediments and the roles of different microbial constituents, and (3) the dominant strains or species in PCB-contaminated sediment microbial communities.
- Studies of aerobic PCB biodegradation under a range of dissolved oxygen conditions indicate that the extent of aerobic biotransformation of PCB compounds is related to the concentration of dissolved oxygen, and that the dependence on dissolved oxygen concentration (> 4 ppm required) is similar to that for other oxygenase-mediated processes. This suggests that knowledge about other coupled systems (such as elimination of ammonia by oxidation to nitrate followed by nitrate-dependent respiration) may be applicable to PCBs. The relatively high dissolved oxygen concentration required for significant aerobic PCB biotransformation activity implies that aerobic processes will be important only in the very-near surface region (e.g., top 1 cm) of river sediments.
- Comparison of congener pair abundances in Aroclors, the original PCB liquid mixtures responsible for contamination in river sediments, to those in field data from contaminated river sediments (1994 data from the Hudson River) has revealed that (a) congeners identified as being correlated in the commercially manufactured Aroclors typically consisted of congeners with the same number of substituted chlorines (homologs), (b) congener proportions reported in the field data were not consistent with Aroclors, indicating that the contaminants are being changed in the environment, and (c) trends observed in the field data congener proportions suggest shifts towards typical dechlorination endpoints. In addition, a numerical analysis of changes in the correlated congener proportions in PCB-contaminated sediment samples from the field identified the most likely PCB compound structures for polychlorinated biphenyl dechlorination similar to those observed in the laboratory by other researchers (that is, compounds with flanked chlorines were most likely to have been removed, followed by compounds with meta chlorines).
- Based on the review of field data on PCB release from sediments, and study of related literature, temperature appears to have a dominant role in governing release of PCBs from contaminated sediments to river water. Results of microcosm experiments indicate that temperature can significantly affect the transport of PCBs in near-surface sediment, especially when microbes are present in the system.