Microbial Degradation of Polybrominated Diphenyl Ethers (PBDEs)

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Aerobic bacteria capable of degrading polychlorinated biphenyls were tested for the ability to degrade PBDEs. Two strains in particular degraded all PBDEs with fewer than six bromines and one completely transformed the original compound releasing stoichiometric quantities of bromide.

Polybrominated Diphenyl Ethers (PBDEs) are flame retardants that have been used for three decades in a wide variety of manufactured materials. The PBDE family comprises 209 different compounds, or congeners, that have different chemical and toxicological properties. Recent discoveries of the endocrine-disrupting ability of some of these compounds as well as exponentially increasing breast-milk concentrations have raised concern about their use and have led to regulatory bans for some of the compounds in California.

Bacteria play an important role in the fate of compounds in the environment. Anaerobic dehalogenating microorganisms can remove halogens from a variety of compounds. Given that the toxicity of PBDEs increases with fewer bromines, it is important to understand whether anaerobic microorganisms can debrominate PBDEs. Aerobic bacteria that degrade polychlorinated biphenyls (PCBs) may be able to degrade PBDEs and could potentially remove PBDEs from the environment. As such, the objectives of our project were to 1) determine whether highly-brominated deca and octa-BDE congeners can be debrominated by anaerobic dehalogenating microorganisms; 2) determine the debromination pathway and 3) determine whether aerobic PCB-degrading bacteria are capable of degrading PBDEs.

Since 2007, we have completed the final objective of this research project. Two known PCB-degrading bacteria, *Rhodococcus jostii* RHA1 and *Burkholderia xenovorans* LB400 were tested for their ability to degrade PBDEs with one to six bromines. Additionally, two related strains, the aromatic-degrading *Rhodococcus sp*. RR1 and the ether-degrading *Pseudonocardia dioxanivorans* CB1190 were also tested. Both RHA1 and LB400 were capable of degrading the mono- through penta-BDEs, and LB400 was able to degrade one of the three tested hexa-BDEs over the course of three days. The extent of degradation varied with more than 90% of the mono- and di-BDEs being degraded whereas between 10 and 45% of the penta-BDEs degraded over the same time period. RR1 and CB1190 only minimally transformed the less brominated congeners (Figure 1).

In order to determine whether the PBDEs were being completely broken down or whether some intermediate was being formed, the samples were analyzed for the production of bromide. Current analytical techniques for detecting bromide did not work for our samples, so a collaboration was set up with Dr. Mehmet Coelhan of the Technical University of Munich, Germany, to develop a new bromide measurement technique that could work in the presence of cells.

Bromide was in fact detected in the RHA1 samples at stoichiometric concentrations, indicating that the PBDE molecule is being entirely degraded. The LB400 samples only

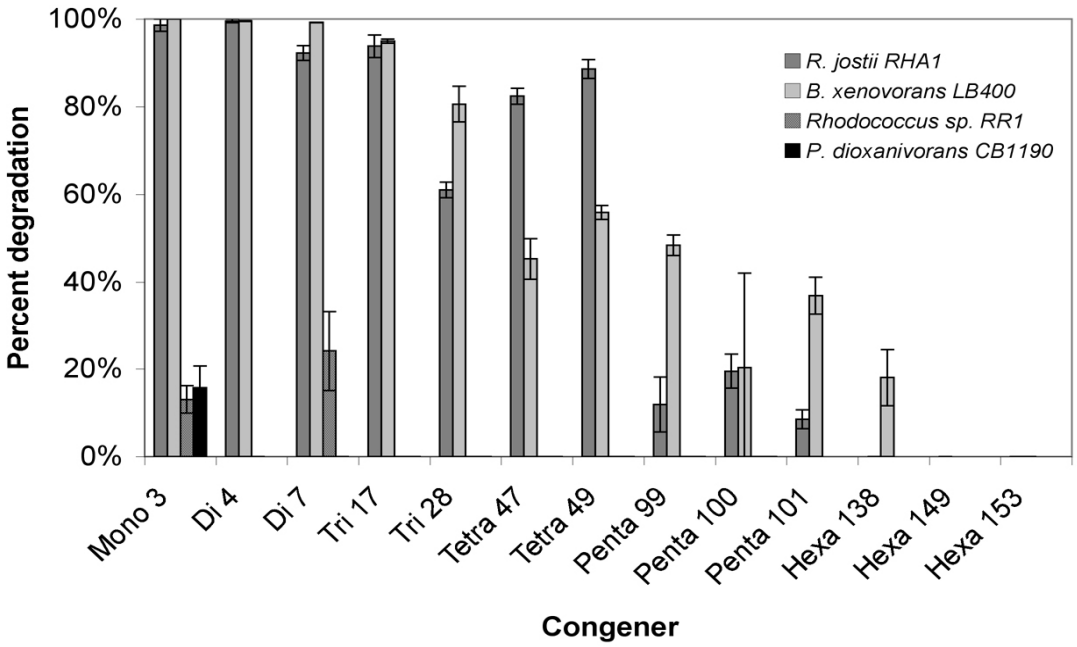

Figure 1. Percent degradation of 13 PBDEs by four aerobic bacteria. Values are averages of triplicates. Error bars represent the standard error.

yielded about 10% of the expected amount of bromide based on the disappearance of the PBDE substrate. GC-MS analysis revealed that the other 90% of the substrate was being transformed to a hydroxylated PBDE. This result is problematic because hydroxylated PBDEs are more endocrine disrupting than the original PBDE.

Publications

Robrock, K.R., P. Korytar, L. Alvarez-Cohen. "Pathways for the Anaerobic Microbial Debromination of Polybrominated Diphenyl Ethers" *Environmental Science & Technology*, 2008, 48 (2) 2845-2852.

Professional Presentations

"Aerobic biodegradation of Polybrominated Diphenyl Ethers (PBDEs) by PCB-degrading bacteria" Invited lecture, Norcal SETAC Conference, Berkeley, CA, May 2008.

Robrock, K., L. Alvarez-Cohen, "Degradation of polybrominated diphenyl ethers by aerobic PCB-degrading organisms." Poster presentation, NIEHS Superfund Basic Research Program Meeting, Duke University, NC, 2007.

Collaborative Efforts

Dr. Mehmet Coelhan at the Technical University of Munich, Germany, helped develop a technique for measuring low concentrations of bromide in the presence of bacterial cells.

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