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Bioremediation of Dioxin-polluted Soil Using Microbial Consortia

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Dioxins are the group of polychlorinated forms of dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs) and coplaner polychlorinated biphenyls, known as toxic and persistent environmental pollutants. How to remedy dioxin-polluted environments is one of the most challenging problems in environmental technology. From ecological and economical viewpoints, biological methods using particular microorganisms or microbial consortia have greater appeal for their potentials than physicochemical ones to be applied to the environmental remediation. Large numbers of microorganisms capable of degrading dioxins and related aromatics have been isolated and characterized. There are three major models of microbial degradation and transformation of dioxins: aerobic degradation by bacterial dioxygenases, reductive dechlorination by anaerobic microorganisms, and fungal oxidation with peroxidases, laccases, or cytochrome *P*-450 [for reviews, 1, 2]. Here I talk about our study on microbial consortia capable of degradation and transformation of PCDD/Fs as well as recent advances in bioremediation techniques for dioxin-polluted soil.

One of the most outstanding recent observations in this area of research is that anaerobic bacteria classified as "*Dehalococcoides*" are capable of dehalorespiration with PCDDs [3, 4]. Our previous study has also suggested that anaerobic bacteria capable of reductive dechlorination of PCDD/Fs coexist with aerobic dibenzofuran-degrading bacteria in soil environments contaminated with high concentrations of PCDD/Fs [5]. Thus, a promising approach to the development of a bioremediation process for dioxin-polluted soil is the combined use of bacteria capable of dehalorespiration with PCDD/Fs and aerobic oxidative degradation of lower chlorinated ones. For this, we have focused on the following subjects in our study: (a) microbial community analysis of anaerobic consortia enriched from dioxin-polluted sediment; (b) elucidation of PCDD/F biodegradation mechanism; (c) development of a new dioxin degradation process using a solid-phase bioreactor.

Regarding subjects (a) and (b), we studied changes in PCDD/F concentration and microbial community structure in microcosms seeded with *Bacteroidetes*, *Firmicutes*, *Proteobacteria*, and *Spirochaetes*. No clones affiliated with the "*Dehalococcoides*" group were found. However, attempts to detect "*Dehalococcoides*" by real-time PCR gave positive results. Despite anaerobic operation of the microcosms, aerobic dibenzofuran-degrading bacteria belonging to diverse taxa were isolated from these microcosms. Most of the dibenzofuran-degrading strains produced yellow metabolites during the degradation, suggesting that lateral dioxygenation is involved in the degradation in these organisms.

Regarding subject (c), solid-phase fed-batch bioreactors for degrading PCDD/Fs with composting of

solid biowaste were operated. A dioxin-polluted soil was added to the reactors, which were then operated with daily loading with biowaste for several months. PCDD/Fs were decreased significantly under both aerobic and anaerobic conditions, but the reduction rate was higher under the latter condition.

In view of the information accumulated to date, a combined process of anaerobic dehalogenation of PCDD/Fs and subsequent aerobic degradation of less halogenated products has a great promise for bioremediation purpose. Although both physiological groups of bacteria coexist in our studied systems as well as in polluted environments, dioxin-polluted sediment or soil. These microcosms were cultivated anaerobically with organic nutrients for several months. The concentration of PCDD/Fs decreased with time in all microcosms. The addition of organic nutrients and H_2 stimulated the reduction of PCDD/Fs. However, mono- and dichlorinated congeners, expected as metabolites of dehalorespiration, were not accumulated in any microcosm (Fig. 1). Changes in bacterial community structure of the acclimated microbial consortia were monitored by quinone profiling, 16S rDNA-based DGGE, and the clone library methods. These consortia were phylogenetically diverse and contained members of the phyla little is known about the interaction between the two groups. Ecophysiological studies with axenic culture or structurally defined microbial consortia capable of dioxin transformation are clearly necessary to exploit bioremediation techniques for practical use.

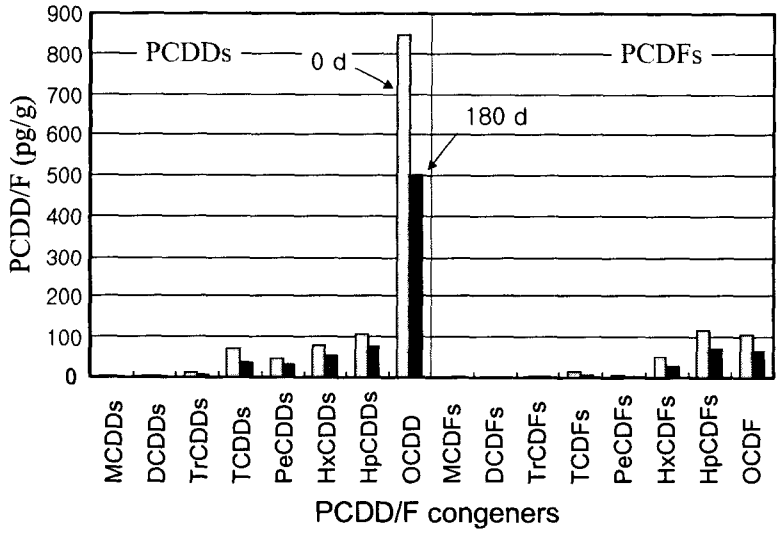

Fig. 1. Reduction of PCDD/Fs during 6 months of anaerobic incubation of a microcosm seeded with dioxin-polluted sediment. Dioxin congener concentrations at the beginning (0d) and after 6 months of incubation (180d) are shown.

References

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