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Integration of Microbial Ecology and Kinetics with Performance of a Hollow-Fiber Membrane Reactor

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Introduction

Perchlorate (ClO_4^-) has recently been listed to the US Environmental Protection Agency's drinking water Candidate Contaminant List due to its interference with hormone production by the thyroid gland (Urbansky and Schock, 1999). Perchlorate is manufactured in large quantities as ammonium perchlorate, primarily for use as an oxidizer in solid rocket propellants. It is also used in fireworks, batteries, and automobile air bags. Although there are many physical treatment options, there is no obvious treatment technology for removing perchlorate from water. Ambient temperature treatment methods using metals, such as zero-valent iron, which successfully remediate chlorinated aliphatic compounds, such as TCE, do not work for perchlorate. Recent studies with rhenium catalysis and sulfide show greater promise for perchlorate reduction, although water treatment technologies based on these new catalysts are not available (Abu-Omar et al., 2000)

Bioremediation of perchlorate-contaminated waters is promising (Logan, 1998; Urbansky, 1998). Although perchlorate only occurs naturally in Chile, bacteria capable of perchlorate degradation appear to be widely distributed in nature at concentrations ranging from one to thousands of bacteria per gram of water, wastewater, sediment, and soil (Coates et al., 1999; Wu et al., 2001). Perchlorate is used as an electron acceptor by some bacteria for cellular respiration and is degraded completely to chloride ion. The bacteria that degrade perchlorate are diverse. Almost all of them fall within new species classifications based on a 16s rDNA classification scheme a recombinant DNA methodology based on the 16s rRNA gene, which can be used to assess the phylogeny of bacteria. Most perchlorate-respiring microorganisms (PRMs) are capable of functioning under varying environmental conditions and use oxygen, nitrate, and chlorate (ClO_3^-) but not sulfate as a terminal electron acceptor. Perchlorate can be successively degraded to chlorate and then chlorite (ClO_2^-) by a novel chlorate reductase respiratory enzyme.

We investigated a hollow-fiber membrane biofilm reactor (HfMBR) for perchlorate removal with hydrogen as electron donor. Pechlorate-reducing bacteria (PRB) were monitored during the HfMBR operation and a novel PRB was identified. The integration of microbial ecology and kinetics with process performance provided insights on how to operate reactor for efficient and cost-effective perchlorate removal.

Materials and Methods

The hollow-fiber membrane bundle was housed by a 1.5cm I.D. PVC tube, and the liquid flow was upward. The fiber was manufactured by Mitubishi Rayon, and its O.D. is 0.027cm. Hydrogen was supplied by a pressurized gas tank. The feed solution was tap water amended with a concentrated stock solution of phosphate buffer and mineral solution. Adding $NaHCO_3$ was to ensure an ample supply of inorganic carbon for autotrophic growth, while the phosphate buffer was added to maintain the pH at 7 for all testing conditions. Phylogenetic analysis, DGGE, and FISH were conducted by the conventional methods with the special primers and oligonucleotide probe for this study.

Results and Discussion

Hydrogen is an ideal electron donor for biological drinking water treatment because it presents no toxicity, is inexpensive, and is unlikely to persist as a source of biological instability in distribution systems. When 1 to 2 mg/L perchlorate was supplied to HfMBR, which was at steady-state with 5 mgN/L nitrate but unacclimated to perchlorate, perchlorate removals increased from 40 to 99% over three weeks. Results showed that biological perchlorate reduction takes place concurrently with nitrate reduction, no specialized inoculation is required. However, nitrate is inhibitory to perchlorate reduction and perchlorate reduction is more pH sensitive than denitrification. Higher hydrogen supply enhanced denitrification and perchlorate reduction. Two perchlorate-reducing bacteria, hydrogen-oxidizing autotroph and mixotroph, and three denitrifying bacteria, all autotroph, were isolated from the HfMBR and wastewater. Two main bands were found in the DGGE analysis on biofilm with nitrate feed after microbial diversity decreased over time. A main band showing a perchlorate-reducing bacterium was found from the biofilm of HfMBR with perchlorate-supply only. Its 16S rDNA sequence showed that it is close to *Dechlorosoma* sp. KJ and *Dechlorosoma* sp. SDGM. The microbial distribution of perchlorate-reducing bacteria in the HfMBR and biofilm was observed with FISH using perchorate-reducing-bacteria-specific oligonucleotide probes.

Reference

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