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Title: Bioremediation of Sediments Contaminated with Polyaromatic Hydrocarbons
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Objectives/Hypothesis

The research in this study focuses on requirements for application of bioremediation technology for cleanup of PAH contaminated sediments. In this project we examined the factors that control the design, operation, and effectiveness of sediment bioremediation processes. Specifically, the following were investigated:

- extent of treatment possible with highly contaminated, aged sediments (as a function of PAH type, bioavailability, and microbial diversity/genotype);
- microbial and physical-chemical parameters that control degradation of high molecular weight PAHs;
- optimization of slurry reactor operation (for example, mixing and/or aeration rates, bioaugmentation, and surfactants to increase bioavailability); and
- use of a solid-phase oxygen source as a pretreatment to prevent volatile organic carbon emissions when highly reduced anaerobic sediments are aerated for PAH bioremediation.

Approach

PAH Biodegradation in Highly Contaminated Sediments

Initial studies focused on the degradation of PAHs in highly contaminated sediments from Utica Harbor (Utica, NY). These sediments (supplied by the Niagra Mohawk Power Company) were contaminated over 70 years ago during the operation of a coal gasification plant, and contain total PAH concentrations as high as 7,000 mg/kg (primarily 2-,3-, and 4-ring compounds). Hence, the contaminants should be highly sorbed and bioavailability should limit both the rate and extent of contaminant biodegradation. These studies will be conducted in small slurry reactors (200ml). Initial experiments addressed rates and extent of degradation achieved under "ideal"laboratory conditions. Additional experiments using these sediments were conducted to investigate adaptation and selection (population shifts) of PAH-degrading organisms during the treatment process.

Parameters that Control Biodegradation of High Molecular Weight PAHs

These studies focused on the effects of multiple contaminants on degradation patterns in slurry reactors. Possible effects include co-oxidation and sequential utilization. Experiments used sediments prepared in-house with defined mixtures (two to four PAHs), and will focus on the influence of 2- and 3-ring PAHs on the degradation of 4- and 5-ring PAHs. Abiotic controls were maintained for all studies using $HgCl_2$ (250 mg/L), and all experiments were conducted at least in duplicate. Initial studies were conducted in a matrix design with sediments contaminated with known levels of PAHs. To avoid volatilization losses, sealed systems were used with adequate headspace to ensure aerobic conditions.

Optimization of Slurry Reactors to Enhance Rates and Extent of Biodegradation while Minimizing Volatilization

A laboratory scale slurry reactor was constructed that was capable of controlling DO and mixing intensities, and equipped with on-line monitoring of CO_2 production and hydrocarbon traps. Reactors were constructed to control gas flow rates (either at preset constant rates or to maintain a constant DO in the reactor) and mixed with variable speed high torque mixers. Initial studies focused on control of gas flow rates to minimize stripping losses. Experiments were conducted under various air flow strategies (constant rate, constant DO) while monitoring biodegradation rates on volatilization losses. Biodegradation rates were quantified by CO_2 evolution and extractions of sediment samples. The possible effects of bioaugmentation on slurry reactor performance were also be studied. Bioaugmentation may be effective for high molecular weight PAHs if population shifts are essential to their degradation.

ORC Control of VOC Emissions from Bioreactors

In previous experiments we found that the initial oxygen demand of anaerobic sediments can be met by aeration and by the addition of hydrogen peroxide. Large amounts of hydrogen peroxide are often required, but hydrogen peroxide at high concentrations is toxic to bacteria (Fiorenza, 1992) and may adversely affect subsequent sediment bioremediation. A new solid metal peroxide may offer a solution to the VOC problem if it can be formulated to the special requirements of bioreactors. The Oxygen Release Compound (ORC) is a magnesium peroxide and breaks down when hydrated to yield oxygen and magnesium hydroxide (milk of magnesia). The parent chemical and the end products are non-toxic and can be disposed without regulatory concern. Experiments to meet the objective of VOC control from disturbed sediments involved a sequential series of experiments to determine the formulation and application methods best suited for use with bioreactors.

Results

This project provided the basis for the design, operation, and management of high solids slurry bioreactors for the cleanup of aquatic sediments contaminated with high mg/kg concentrations of PAH compounds. We focused on in situ bioreactors, but the data obtained was applicable to ex-situ reactors where indicated by engineering or regulatory concerns. We will focus our attention on the important remaining issues–bioavailability requirements, efficacy of bioaugmentation, process design, and control of VOC emissions.

Summary of Results

- Developed a high rate bioreactor process to cleanup PAH contaminated sediments;
- Employed bioaugmentation to decrease volatile emissions from bioreactors;
- Explained the observed lack of effect of surfactants on bioavailability of contaminants in sediments; and

- Partnered with a consulting firm (RETEC) to demonstrate bioreactor treatment of contaminated sediment “Hot Spots”.

Supplemental Keywords
Bioavailability, volatile organics, and remediation

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