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Bioremediation of Contaminated Sediments and Dredged Materials

Background

The Houston Ship Channel is a crucial component of the City of Houston and Gulf region economies; the recreational and fisheries benefits of the Galveston Bay estuary are world renowned. Plans to develop the channel, however, must contend with the environmental repercussions of dredging operations. During dredging, sediments are resuspended and contaminants escape into the water column, where they are accumulated by aquatic plants and animals and then enter the food web. The challenge, then, is to enlarge the channel and protect the Galveston Bay fisheries while avoiding environmental pollution when moving sediments that are heavily contaminated with toxic metals.

Despite decades of research, surprisingly little is known about successful remediation of contaminated sediments. The current approach to sediment management and remediation is generally limited to no action at all, or dredging and subsequent land or aquatic disposal. Although biodegradation and entombment may eventually inactivate the pollutants, these natural processes are too slow to prevent release of the compounds into the ecosystem.

Rice University researchers have therefore undertaken a search for ways to increase the rate at which microorganisms degrade toxic substances. They are particularly interested in polycyclic aromatic hydrocarbons (PAHs), which result from direct discharge of petroleum-containing wastes, coal gasification, and combustion processes, and may be carcinogenic. Naphthalene, phenanthrene, fluorene, chrysene, anthracene, and acenaphthalene are all PAHs commonly found in these sediments. All are also biodegradable under aerobic conditions, but their degradability varies as a function of their molecular size and structure as well as the redox characteristics of the sediment or sediment / water system.

The goals of this project are to:

- identify and quantify the microbial and physical-chemical parameters that control the rate and extent of biodegradation in sediments;
- determine the extent of treatment possible with highly contaminated, dredged sediments;
- determine the feasibility of *in situ* bioremediation of sediments and dredged materials.

Progress

Working with the Texas Water Commission, the researchers have collected sediment samples from four sites in the Houston Ship Channel and from Dickinson Bayou. This bayou has been identified as one of the most highly contaminated in the Galveston Bay area, as it has received large amounts of produced water from oil fields (water that coexists with crude oil and is disposed of during oil production).

Degradation of toxic substances, in this case PAHs, often produces toxic by-products that are more recalcitrant to degradation than the parent compound. Researchers are looking for microbes to completely mineralize PAHs, i.e., to degrade the toxic compounds all the way to carbon

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Summary of the Problem

Focusing on petroleum hydrocarbon degradation in the Houston Ship Channel and Galveston Bay area, researchers at Rice University are evaluating the potential of bioremediation processes for cost-effective treatment and risk reduction of contaminated sediments and dredged materials.

As a general class, petrochemicals are known to be biodegradable, so biological processes offer the potential for low-cost and effective treatment. The Rice team is focusing their studies on several polycyclic aromatic hydrocarbons (PAHs), both individually and in mixtures, because they are particularly abundant in the Ship Channel sediments. Various factors influence the rate and extent of biodegradation—redox conditions, ability to induce desorption from the sediment, solubility of the PAHs, metabolic capabilities of the indigenous microbes, nutrient and dissolved oxygen levels, preferential utilization by the organisms of one PAH over others in a mixture, and so forth. Through a better understanding of these parameters, researchers hope to learn how to effectively transfer bioremediation technology from ideal laboratory conditions to actual contaminated field sites.

dioxide. To date, they have confirmed the mineralization of naphthalene, fluorene, and phenanthrene in Dickinson bayou sediments, and know that naphthalene is being mineralized in the Houston Ship Channel sediments as well. It thus appears that microorganisms that degrade PAHs exist naturally in these sediments. However, while degradation begins within 24 hours, complete disappearance takes much longer.

In a full-scale operation, it may be possible to raise the biodegradation rate by increasing the population of PAH-degrading organisms. Therefore, the researchers are using several methods to develop PAH-degrading organisms. They started with a culture from the Dickinson Bayou sediment and developed an elevated population of PAH degraders that occurs naturally in this sediment. The culture has been maintained and separate strains of naphthalene, fluorene, and phenanthrene degraders have been isolated. Two strains that grow only on fluorene have been studied more intensively so far. The cultures can be enriched on fluorene, but growth is very slow (several weeks). To hasten growth requires nutrient broth, but then the microorganisms lose their ability to degrade fluorene. It appears best to use mixed cultures that contain one strain to degrade fluorene, and others to degrade the by-products of fluorene degradation all the way to complete mineralization.

Current Studies

PAHs are strongly sorbed (bound) to sediments, so several studies have focused on the relationship between resuspension and biodegradation in laboratory-scale slurry reactors. A slurry reactor is an enclosed system in which sediments and water are maintained in a homogeneous slurry over a fixed period of time. Phenanthrene was selected as a model PAH, and several parameters were varied to determine their effect on rate and extent of mineralization.

Mixing rapidly increased the bioavailability of contaminants by hastening and augmenting their release into the aqueous phase; it also maintained oxygenation of the slurry. Mineralization in mixed reactors was significantly greater than in unmixed systems. Nutrient amendments had no effect on biodegradation rates, but augmenting the reactors with aged slurry eliminated an initial lag period. From these results it appears that sequential treatment of small areas of highly contaminated sediments in *in situ* batch reactors would be most effective.

Other studies have been equally successful in reversing adsorption of fluorene to sediments, even at high concentrations. Again, desorbing the compound augments its availability to the microorganisms, allowing more rapid and extensive mineralization.

Future Work

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