Stimulation of Methyl Tert-butyl Ether Biodegradation Using A Co-Substrate Approach

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Research Objectives

Methyl tert-butyl ether (MTBE) is an "oxygenate" that is added to gasoline to promote cleaner combustion. The use of MTBE has become widespread as a result of U.S. Environmental Protection Agency programs targeted at reducing carbon monoxide and ozone air pollution. An unintended consequence of using oxygenates to control air pollution has been that service stations, fuel transfer terminals, farms and other places where gasoline is used or stored are now sources for the release of MTBE into the environment. Not surprisingly, there are many instances where gasoline spills and leaks have resulted in the contamination of groundwater with MTBE. This problem is particularly acute in California, where MTBE-containing fuels have been used since the early 1990s and groundwater resources are highly valued.

There is currently no well-established technology for treating MTBE-contaminated groundwater. The objective of this research is to develop a biological treatment technology. It has been shown that MTBE is biodegradable, therefore, biological treatment is a promising technology; however, the mechanism by which microorganisms degrade MTBE is unknown. Without an understanding of the physiology of MTBE biodegradation, the operation of MTBE biodegrading treatment systems remains haphazard and unreliable.

The objective of this ongoing research is to increase the efficiency of MTBE biodegradation in a "fluidized-bed" bioreactor. Research is being conducted to develop methods for rapid reactor start-ups and for lowering MTBE effluent concentrations from the reactor. A typical reactor start-up can take more than 100 days before MTBE removal is achieved. Furthermore, once MTBE is being removed, the removal will only be 99% efficient, whereas new regulations will require removals of 99.9% or greater.

In order to increase reactor treatment efficiency, it is necessary to understand the fundamental processes responsible for MTBE biodegradation. The hypothesis for this research is that MTBE is driven by a co-metabolic process; i.e., a process in which enzymes produced for an unrelated purpose (such as energy metabolism) can also transform MTBE by "accident." It is further hypothesized that if the proper co-metabolic additive can be found, the co-metabolite can be used to stimulate MTBE degrading microorganisms; thus, reactor start-up time can be shortened and removal efficiency can be improved.

Approach

The approach taken was to conduct field and laboratory research in parallel. Laboratory studies consisted of batch reactions in sealed vials where MTBE removal under different conditions was measured over time. Samples of full-scale, up-flow, MTBE-degrading biological reactors containing bacteria grown as a biofilm on activated carbon were transported to the laboratory and tested for stimulation of MTBE-degrading activity. Compounds tested for stimulation included gasoline components (such as toluene), suspected MTBE biodegradation products (such as tert-butyl alcohol) and contaminants commonly found in industrial grade MTBE (such as methanol). It was observed that the reactor had "iron-bacteria" in the biofilm, so conditions conducive to iron-bacteria were also tested for stimulation of MTBE degradation activity.

When a potential co-substrate was identified, field studies were conducted at the Sparks Solvent Fuel Site (SSFS) in Sparks, Nevada. MTBE-contaminated groundwater at SSFS is now being treated by a pair of six-ft-diameter Envirex/U.S. Filter up-flow, aerobic, fixed-film bioreactors. Controlled studies can be conducted in the field because the reactors are operated in parallel, allowing one reactor to be treated and the other to serve as a control. In the field tests, compounds found to be stimulants were added to one of the two reactors and the effect on the added compound on MTBE treatment was evaluated.

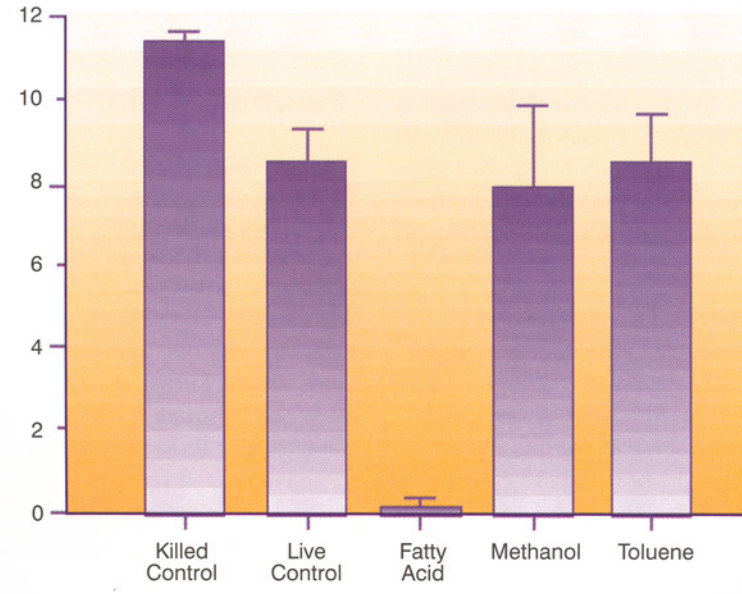

Figure 1. Testing of potential co-metabolites for stimulation of MTBE biodegradation.

Results

Laboratory studies were used to evaluate the potential of more than two dozen compounds as potential co-metabolic stimulants of MTBE biodegradation (Figure 1). Organic compounds (fatty acids) known to support the growth of iron-bacteria stimulated