Report for 2001MT281B: MTBE Biobarriers in Stream Sediments

- Other Publications:
  - Meiser, Elsa Emilie. 2002. The oxygen dependence of the degradation rate of Methyl tert-Butyl Ether by a bacterial isolate. Master's Thesis, Montana State University Department of Civil Engineering.

Report Follows:

Oxygen Dependence of the Degradation Rate of Methyl *tert*-Butyl Ether by a Bacterial Isolate

By Elsa Meiser

Abstract

Methyl *tert*-Butyl Ether (MTBE) is a fuel oxygenate added to gasoline to boost octane and reduce carbon monoxide emissions. Studies indicate that MTBE is cometabolically oxidized by monooxygenase (MO) enzyme activity that is induced by the oxidation of n-alkanes under aerobic conditions. The MO enzyme requires molecular oxygen to oxidize the target chemical. The Michaelis-Menton model is a mathematical model that describes the enzyme-mediated dependence of reaction rate on a given substrate. The Hill model further describes enzyme activity when cooperativity among enzymes has been introduced. This study investigated the Michaelis-Menton and Hill models as appropriate models to describe the dependence of MTBE disappearance rate on dissolved oxygen concentration by a bacterial isolate. It was found that the Hill model represents a better model than the Michaelis-Menton model for the given data as determined by regression analysis. Furthermore, MTBE disappearance rate also has a dependence on MTBE concentration that must be incorporated into a mathematical model to predict the behavior of this system.

Research Objectives

The purpose of this research was to determine the dependence of MTBE disappearance rate on oxygen by a particular bacterial isolate, PM1. Two mathematical models describing reaction rate dependence on a substrate in the presence of enzyme activity were analyzed to determine which provided the best model fit for the data. Regression analysis were performed and compared between the two models.

Methodology

Experiments were run in microcosm batch format. The microcosms were adjusted to different levels of dissolved oxygen and given MTBE as a sole carbon and energy source. The bacterial isolate used in these experiments was PM1, a culture known to be capable of utilizing MTBE.

In each experiment, the microcosms were monitored over the course of seven days, the time that it took to fully deplete approximately 14 mg/L of MTBE. Samples were removed and analyzed every other day. Measurements were made of MTBE and TBA concentration, optical density, and headspace concentrations of oxygen, carbon dioxide and nitrogen.

The data were used to calculate MTBE disappearance rates in the microcosms. MTBE disappearance rates were regressed against dissolved oxygen concentrations. Model fits were performed using an algorithm to minimize the sum of the squares of the residuals in a non-linear regression scheme. The goodness of fit was determined by R^2 value. R^2 values were compared between the Michaelis-Menton and Hill models, both with and without taking MTBE concentration into account.

Principal Findings and Significance

The Hill model accounting for MTBE concentration was found to have the best fit for the data. Recall that the Hill model takes cooperativity between enzymes into account. Cooperativity refers to the phenomenon in which initial enzyme activity increases the activity of subsequent enzymes. This model is characterized by regions in which MTBE disappearance rate increases rapidly over short increases in dissolved oxygen. Above a given level of dissolved oxygen, which ranges from 0.5 to 2 mg/L for the given data, MTBE disappearance rate reaches a maximum. Thus, above this level of dissolved oxygen, MTBE disappearance rate is independent of the dissolved oxygen concentration.

It was found that the data adjusted for initial MTBE concentration produced better model fits than data in which the MTBE concentration was not taken into account. Apparently, the behavior of the MTBE disappearance rate is more complex than can be described by either the Hill or the Michaelis-Menton model, which in this case take only the substrate oxygen into account.

These findings suggest that oxygen application schemes for the purpose of enhancing natural attenuation or bioaugmentation would greatly assist the ability of the microorganisms to degrade MTBE. Furthermore, increasing dissolved oxygen to above approximately 2 mg/L would optimize the MTBE degradation rate. Increases in dissolved oxygen above this level would not be effective in increasing the MTBE degradation rate.

Publications/Citations

A Master's thesis was prepared from these findings.

This project has not yet been submitted elsewhere for publication or presentation.

Student Support

Master's candidate, Civil Engineering.

Notable Achievements and Awards

I will let you know after I present my finding publicly!