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Inhibitory and Synergistic Effects during Biodegradation of Mixed Contaminants at an Industrial Site in South America

Paola Barreto (paola.barretoquintero@ch2m.com) (CH2M Hill, Philadelphia, PA, USA)
David Freedman and María Lemes (Clemson University, Clemson, SC, USA)
James Henderson (DuPont, Charlotte, NC, USA)
E. Erin Mack (DuPont, Wilmington, DE, USA)
Carol Mowder (CH2M Hill, Baltimore, MD, USA)

Background/Objectives. This study was conducted for a large industrial facility in South America with a complex mixture of constituents of concern (COCs) in soil and groundwater, including chlorobenzenes, chloroanilines, and nitroaromatics. The overall objective was to evaluate the potential inhibitory effects of individual COCs on aerobic biodegradation of chlorobenzene (CB) and 1,2-dichlorobenzene (DCB), and anaerobic reduction of 2,6-dinitrotoluene (DNT) and 4-nitrotoluene (NT). Chemical oxidation is being considered as a potential method of source zone treatment, so the inhibitory effects of chemical oxidation byproducts were also evaluated. Interactions among these COCs and the chemical oxidation byproducts during biodegradation have not previously been evaluated.

Approach/Activities. Using soil and groundwater from the site, enrichment cultures were developed that aerobically degrade CB (35 mg/L) and 1,2-DCB (7.5 mg/L) and anaerobically degrade 2,6-DNT (11 mg/L) and 4-NT (7.6 mg/L). Lactate was used as the electron donor for reduction of the nitrotoluenes. The enrichment cultures were then exposed to other COCs (2,4-DNT [0.6 mg/L], 4-isopropylaniline [IPA; 5.9 mg/L], 1,2-dichloroethane [DCA; 1.5 mg/L], and 1,4-dioxane [2 mg/L]) to determine their effect on the rate and extent of biodegradation. To evaluate the potential inhibitory effects of chemical oxidation byproducts, a stoichiometric dose of alkaline activated persulfate (27.8 g/g contaminant) was used for chemical oxidation of a mixture of the aforementioned eight COCs; the resulting groundwater was then diluted 10-fold (v/v) in uncontaminated groundwater or in the enrichment culture inoculum.

Results/Lessons Learned. 2,4-DNT, 4-IPA, 1,4-dioxane, and 1,2-DCA did not inhibit the rate or extent of aerobic CB degradation. The 1,2-DCB aerobic degradation rate was decreased only by the presence of 4-IPA, although no effect occurred at a lower level (2.8 mg/L of 4-IPA). CB and 1,2-DCB served as primary substrates for aerobic cometabolism of 2,4-DNT and 4-IPA, but not 1,4-dioxane or 1,2-DCA. This indicates that the aromatic oxygenases required for metabolism of CB and 1,2-DCB are also reactive with 2,4-DNT and 4-IPA. The presence of the co-contaminants had no significant inhibitory effect on the rate or extent of anaerobic reduction of 2,6-DNT or 4-NT to aminotoluenes.

Alkaline activated persulfate removed 50-100% of the COCs following 26 days of exposure. However, there was no significant decrease in chemical oxidation demand, suggesting that the extent of oxidation was minor. The rate of biodegradation of CB, 1,2-DCB, 2,6-DNT and 4-NT decreased in the presence of product water from chemical oxidation following a 10-fold dilution (v/v). Nevertheless, complete biodegradation did eventually occur, indicating the inhibition was transient. The source of the inhibition has not yet been determined. pH was ruled out as a factor, since the pH of the chemical oxidation water was neutralized prior to adding it to the enrichment cultures.

The results of this study indicate that the co-contaminants evaluated (2,4-DNT, 4-IPA, 1,2-DCA and 1,4-dioxane) are not a cause for concern with respect to aerobic biodegradation of CB and

1,2-DCB or anaerobic reduction of 2,6-DNT and 4-NT. The transient inhibitory impact of groundwater from chemical oxidation of the COC mixture is a potential concern, although decreased impacts are expected with further dilution.