The potential for reductive dehalogenation of chlorinated phenol in a sulphidogenic environment in *in situ* enhanced biodegradation

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Abstract

An investigation of the reductive dechlorination of 2, 4, 6-trichlorophenol (2, 4, 6-TCP) under sulphate-reducing conditions was made. Sulphate-reducing and dechloro-respiring activities were studied in a mixed microbial population operated in batch-fed as well as continuous pine chip-packed fluidised bed reactors. Results showed that reductive dechlorination of 2, 4, 6-TCP by the dechloro-respiring bacteria may be indirectly stimulated by the fermentative activity of the sulphate-reducing population affected by sulphate and lactate concentrations. Sulphate was administered in excess (900 mg·ℓ^{-1}) and limiting (110 mg·ℓ^{-1}) concentrations. At these concentrations, SO_4^{2-} was available in quantities sufficient and lower than that required to bring about consumption of lactate. Transformation to 2,4-dichlorophenol (2,4-DCP), 4-chlorophenol (4-CP) and phenol was enhanced in sulphate-limiting conditions with average 47.7% TCP reduction compared to 11.6% in sulphate-enriched administered reactors. The potential application requirements for dechlorination under sulphate-reducing conditions for *in situ* biodegradation are considered. The input electron donor: SO_4^{2-} ratio is manipulated to effect accelerated dechlorination rates for chlorinated organic compound-contaminated soil/groundwater bioremediation applications where oxygen is frequently limited.

Keywords: dehalo-respiration, enhanced biodegradation, reductive dechlorination, sulphate reduction, trichlorophenol

Introduction

The investigation of dehalogenation in the presence of alternative electron acceptors is a subject of some interest given that little is known about the role that these electron acceptors play in dehalo-respiration metabolism. The potential application of their activity in reductive dechlorination to bio-remediate chlorinated compound-contaminated soil and groundwater has not been actively considered.

Anaerobic dehalogenation reactions have been studied in various habitats and are generally found in environmental samples where methanogenesis occurs but they are found less frequently when sulphate or nitrate-reducing conditions predominate (Colberg, 1990; Gibson and Suflita, 1990). Since sulphate is a predominant electron acceptor, especially in marine and intertidal environments, sulphate reduction is the main pathway for carbon metabolism and may be the dominant electron acceptor influencing anaerobic degradation of halo-organic compounds (Häggblom and Young, 1995). Some reports indicate that sulphate appears to inhibit anaerobic degradation of halogenated compounds (Colberg, 1990; Gibson and Suflita, 1990). However, these studies were frequently conducted by the addition of sulphate to exclusively methanogenic-adapted cultures. These cultures were previously able to transform the chlorinated compounds under said conditions but supplementing SO_4^{2-} obstructed or limited degradation. Since the micro-organisms were not acclimatised to sulphidogenic conditions, it was perhaps prematurely presumed that sulphate inhibits dechlorination.

Reports that demonstrate dehalogenation with mixed undefined cultures have been described (Cabirol et al., 1998; Häggblom and Young, 1995; Kohring et al., 1989). Some of these studies suggested the inability of a culture to dehalogenate the halogenated compounds in a sulphidogenic environment, or dehalogenation reactions were not tested under sulphate-reducing conditions though the cultures were shown to dehalogenate the halogenated compounds in the absence of sulphate. The cultures were able to utilise sulphate and other sulphur oxy-anions as electron acceptors. However, studies by Häggblom and Young (1995) and Kohring et al. (1989) that employed exclusively sulphidogenic-acclimated cultures showed that reductive dehalogenation could be coupled to sulphate reduction.

Various dehalo-respiring bacteria have since been isolated, identified and applied in pure culture studies to assess dechloro-respiring activity (De Weerd et al., 1990; Drzyzga et al., 2001; Gerritse et al., 1998). The hypothesis that reductive dechlorination by dechloro-respiring bacteria occurs in a synergetic relationship with sulphate-reducing bacteria (SRB) gained momentum after co-cultures were identified in soil contaminated with tetrachloroethylene (PCE) (Drzyzga et al., 2001; Gerritse et al., 1998). Employing a pure co-culture of the sulphate-reducing *Desulfovibrio* species and the dechloro-respiring *Desulfitobacterium frappieri* TCE1 first elucidated the actual mechanism (Drzyzga et al., 2001). Recently, Drzyzga and Gottschal (2002) operated the sulphate reducer *Desulfovibrio fructosivorans* and *D. frappieri* TCE1 in

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