Insights into Variability of Cometabolic Degradation Kinetics of 1,4-Dixoane and Co-contaminants under Prolonged Starvation Conditions

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Background. Aerobic cometabolic biodegradation has been shown to degrade a suite of chlorinated solvent compounds and emerging contaminants, such as 1,4-dixoane (1,4-D), 1,2,3-trichloropropane, and n-nitroso-dimethylamine. It is generally believed that cometabolic processes cannot be sustained without primary substrate, which serves as an energy and sometimes also a carbon source. When reducing energy obtained from primary substrate is used up, cometabolic biodegradation is expected to stop. To understand the effects of lacking primary substrate on the longevity of stimulated aerobic cometabolic biodegradation in situ, the trends of stimulated in situ microbial degradation activity on 1,4-D, trichloroethene (TCE), and 1,2-dichlorethane (1,2-DCA) during a field pilot test were monitored under the starvation conditions (i.e., no primary substrate addition).

Approach/Activities. A field pilot test for aerobic in situ cometabolic biodegradation of 1,4-D and co-contaminants was conducted at the former McClellan Air Force Base (McAFB), in California. The primary substrates, propane and oxygen of high concentrations, were added intermittently at a variable frequency (from several times per day to two times per week) into recirculated groundwater to stimulate and maintain indigenous aerobic cometabolic microbial activity in situ for the treatment of a dilute plume. The total concentration of all contaminants was approximately 50 µg/L. The treatment results showed that the stimulated in situ bioreactor could treat all contaminants to the levels <1 µg/L. During the course of continuous treatment, there was a period of two weeks without any propane and oxygen addition while the contaminant mas flux continued feeding into the in situ bioreactor. The treatment efficiency remained stable for all contaminants, signifying the endurance of the stimulated cometabolic degradation activities. A similar degree of endurance of aerobic cometabolic biodegradation of 1,4-D was also observed in a laboratory treatment study. The bioreactor was then stressed with insufficient oxygen to complete propane oxidation; the treatment efficiency dropped noticeably for all contaminants. The prolonged starvation conditions were then applied (i.e., no propane addition) for a period of a month. It was found that 1,4-D and TCE treatment efficiency drooped steadily and significantly, but 1,2-DCA treatment efficiency was not affected by the starvation conditions. A literature review on microbial activities under starvation conditions was conducted to better understand whether the observations can be explained through microbial physiology, biochemistry, and ecology.

Results. The observed prolonged cometabolic activity under the starvation conditions suggests that enzymatic reactions (or potentially types of microorganisms) responsible for cometabolic degradation of 1,2-DCA be different from 1,4-D and TCE because 1,2-DCA degradation was not affected. It is possible that the intermittent addition of high concentrations of substrates might help maintain diverse types of microorganisms that can utilize propane and oxygen at very different magnitude of concentrations and potentially favor selection of a microbial population that could thrive under a low frequency (at most two times a day) of cyclic exposure of substrates. It is possible that, for some microorganisms, internal storage compounds might be formed to cope with starvation during the cyclic exposure to the substrates. Although the concentrations of contaminants were too low to support the growth for the microorganisms that degrade the contaminants, it is likely that contaminant-degrading organisms might still be able to obtain some energy and carbon from the cometabolic processes for cell maintenance. The evidence to support these hypotheses and how a better understanding of this phenomenon can help engineer the cometabolic processes will be discussed.