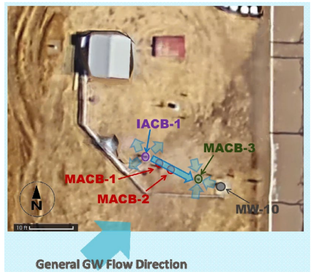
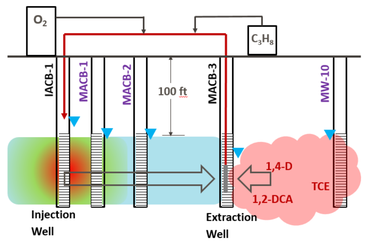
Insights into variability of cometabolic degradation kinetics of 1,4-dioxane and co-contaminants under prolonged starvation conditions

Min-Ying Jacob Chu
Haley & Aldrich, Inc.

Background

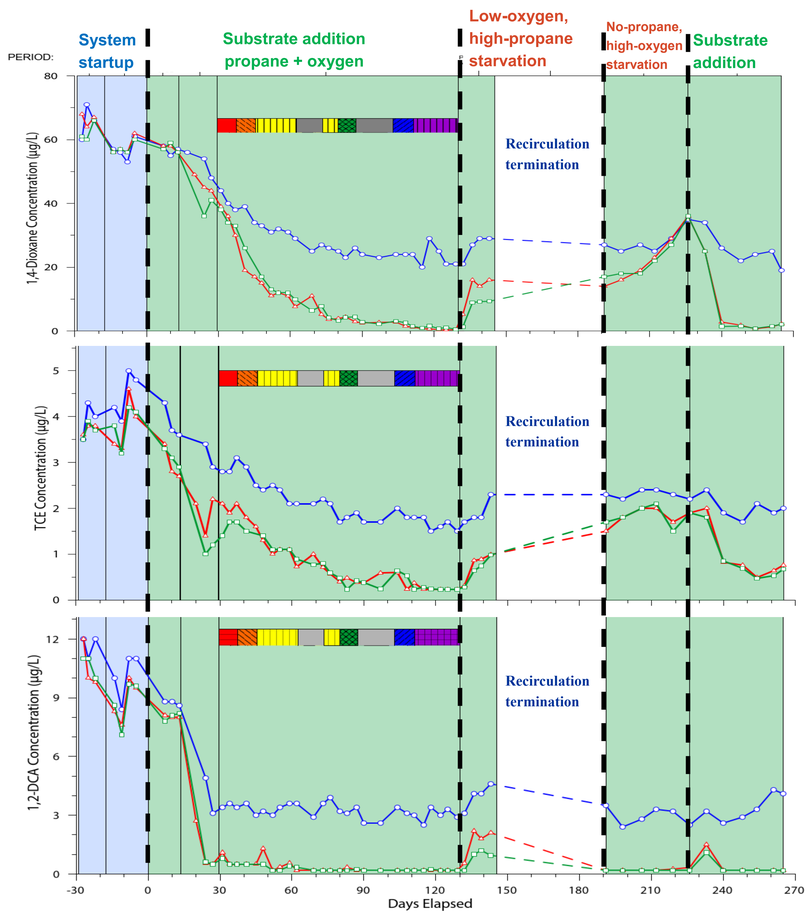
Aerobic cometabolic biodegradation (ACB) has been shown to degrade a suite of chlorinated solvent compounds and emerging contaminants, such as 1,4-dioxane (1,4-D), 1,2,3-TCP, and NDMA. It is generally believed that cometabolic processes cannot be sustained long without primary substrate. When reserved energy obtained from primary substrate is used up, ACB is expected to stop. To understand the effects of lacking primary substrate on the longevity of stimulated ACB activity in situ, the trends of stimulated in situ microbial degradation activity on 1,4-D, TCE, and 1,2-DCA during a field pilot test were monitored under starvation conditions (i.e., no primary substrate addition).





Treatment efficiency of ACB for a dilute plume at the former McClellan AFB

Chemical	C_{up} (ppb)	C_{inj} (ppb)	C_r (ppb)	Site-Specific Cleanup Goal	Single Pass Efficiency	Overall Efficiency
1,4-D	66	21	0.77	**6.1**	~ 96%	~ 99%
1,2-DCA	11.7	2.9	< 0.18	**0.5**	~ 97%	~ 99%
1,1-DCE	1.3	0.3	< 0.2	**6**	~ 67%	~ 92%
TCE	3.9	1.5	0.24	**5**	~ 84%	~ 93%



Degradation rate variability under starvation conditions

- 1,2-DCA degradation lasted approximately 3 months under the starvation conditions of low-oxygen or no-propane-addition conditions. When oxygen became available, 1,2-DCA was degraded quickly.
- Some TCE degradation was observed over the period of 3 months under both starvation conditions. More oxygen during the no-propane-starvation period did not increase degradation rate.
- 1,4-D degradation was affected by the low-oxygen conditions. The no-propane-starvation conditions eventually resulted in a complete loss of 1,4-D degradation activity (about 2-3 weeks).

Possible explanations of the observations

Low-oxygen, high-propane-concentration conditions:

- Many aerobic bacteria can metabolize under microaerobic conditions. At a low dissolved oxygen level, degradation of contaminants may still sustain by stimulated microbial population at a lower rate. The degradation activity for all contaminants was reduced by a similar extent, suggesting a common factor for observed lower activity.

No-propane, high-oxygen starvation conditions:

- Starvation may enhance expression of monooxygenases (R. jostii RHA1 and PrMO). Some ACB bacteria may use intracellular storage compounds to sustain contaminant degradation.
- 1,2-DCA is likely to be degraded by some common enzymes expressed under organic substrate conditions.
- Different types of enzymes and/or different groups of microorganisms are likely responsible for degradation variability. It is evidenced by the observation that enzymes/bacteria responsible for 1,4-D degradation are not as resilient as those for 1,2-DCA and TCE degradation.